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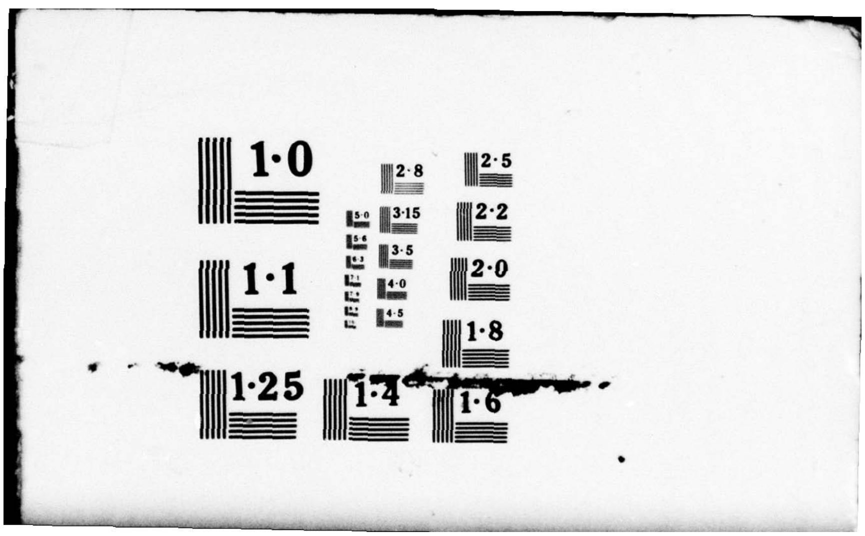
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Interim Technical Report Number ITR-78-14

The Team-Training Load As A Parameter Of Effectiveness For Collective Training In Units

By

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Earl A. Alluisi, and Raymond H. Kirby

Organizations and Systems Research Laboratory
U.S. Army Research Institute for the
Behavioral and Social Sciences
Department of the Army

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FOREWORD

This report was prepared by Drs. Ben B. Morgan, Jr. (Associate Professor of Psychology and Director), Glynn D. Coates (Associate Professor of Psychology and Associate Director), Earl A. Alluisi (University Professor of Psychology), and Raymond H. Kirby (Professor of Psychology and Deputy Director) of the Performance Assessment Laboratory, Department of Psychology, Old Dominion University, Norfolk, Virginia 23508. Contributions to the preparation of the appendix were also made by Mr. Curtis E. Sandler (Research Associate, Performance Assessment Laboratory), as listed there and in the Table of Contents. The research reported here was supported by U.S. Army Grant No. DAHC19-76-G-0015, "Parameters of Effectiveness for Collective Training in Units: I. The Team-Training Load," Project Number 2Q161102B74F, monitored by the Organizations and Systems Research Laboratory, U.S. Army Research Institute for the Behavioral and Social Sciences, Department of the Army, Room 6N12, 5001 Eisenhower Avenue, Alexandria, Virginia 22333. In addition, partial support for the technical preparation and reproduction of this report was provided by the Old Dominion University Research Foundation, Old Dominion University, Norfolk, Virginia 23508.

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SUMMARY

This report summarizes the results of two series of studies of team training conducted during the summer of 1977. In each of 10 studies, 5 subjects worked together as a team for 8 hours per day over 6 consecutive days; during their first 48 hours of work, each team was trained to perform the 6 tasks that constitute the synthetic work presented with the Multiple-Task Performance Battery. The 10 teams consisted of different combinations of the total of 20 undergraduate male volunteer subjects to provide team-training loads (percentages of untrained team personnel) ranging from 0 to 100 percent in 20 percent steps. The data of the 10 studies were combined to permit analysis of the effects of team-training loads ranging from 0 to 100 percent in 10 percent steps, and the effects of team-training load on training and performance effectiveness were thereby assessed.

The results indicated that the substitution of untrained personnel into a trained team reduces the performance effectiveness of the team (in terms of both average individual-skill performances and team-skill performances) in direct proportion to the percentage of untrained team personnel. In all cases, this was a function of the lower performances of the untrained team members; performances of the trained individuals were <u>not</u> adversely affected by increases in the team-training load. Both individual- and team-skill performances recovered to asymptotic (baseline) levels after a constant amount of collective training for all team-training loads. Thus, the percentage of untrained personnel in the team had no influence on the effectiveness of the training. Differences in individual- and team-skill performances suggested that the latter are more resistant to adverse effects at the lower levels of team-training loads; with 10 percent untrained personnel, team-skill performances were only slightly affected. The implications of these results for optimizing team-training strategies and maintaining high levels of team-performance effectiveness are discussed, and verification by field testing is recommended.

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INTRODUCTION

The individual-training effort within the Department of Defense is both enormous and costly; e.g., during fiscal year 1976, 1.7 million officers and enlisted personnel completed some type of formal individual military training at a cost of over $7.1 billion (Alluisi, 1976a). As pointed out by Secretary Schlesinger in the Annual Defense Department Report for 1975, at any given time "about one-sixth of all military personnel--students and trainees, instructors and support personnel--are engaged in the training mission and therefore unavailable for duty in operational units..." (Schlesinger, 1974).

Typically, the military departments have provided major portions of military training through institutions--training commands, schools, and installations. This is especially so for "individual training," which with few exceptions is provided exclusively by designated military training units. As a result of this approach, most spending for defense training research and development has been in support of individual training, with little or no funds provided until recently for crew, group, team and unit (CGTU) training research and development (cf. Alluisi, 1976a).

Proponents of the institutional-training emphasis argue that it contributes substantially to the maintenance of combat readiness within operational units and that it is <u>more efficient</u>, in terms of both the logistics of training and the utilization of available manpower. They contend (a) that individuals should be fully trained when they reach their units of assignment, (b) that the assignment of untrained (or partially or poorly trained) individuals will reduce the combat readiness or performance effectiveness of the unit, and (c) that the combat readiness of an operational unit will be diminished further in direct proportion to the extent the unit is required to allocate its resources for collective training. Problems associated with the transfer of training from the institutional

situations to the conditions of collective performances in units are generally ignored, and emphasis is placed--usually without sufficient supporting data--on the argument that increased unit-training obligations will necessarily reduce a unit's operational combat readiness.

Recently, however, increased attention has been given to collective CGTU training, especially in operational Army units. The U.S. Army Training and Doctrine Command (TRADOC) has stressed the need for increased emphasis on collective training in units, in hopes of increasing both training effectiveness and the performance efficiency of operational units. Also, one of the five general recommendations made by the Defense Science Board (DSB) Task Force on Training Technology, called for the Department of Defense to "increase technology-based funds for training technology R&D in support of crew, group, team, and unit (CGTU) training" (Alluisi, 1976a; p. xv; 1976b). The need for increased Defense R&D on CGTU training has also been noted in state-of-the-art reviews prepared for the Office of Naval Research (Collins, 1977), the Chief of Naval Education and Training (Hall and Rizzo, 1975) and the Defense Advanced Research Projects Agency (Wagner, Hibbits, Rosenblatt, and Schulz, 1977).

Proponents of the CGTU-training emphasis have argued--again, without much supporting data--that collective training within the unit is <u>more effective</u> than individual training in institutions because of the low-positive (or even negative) transfer from such institutional training to operational unit performance situations. They contend that more collective training should be conducted in the unit, with individuals assigned to operational units for such collective training as early in the training cycle as possible, and certainly earlier than has been customary under the traditional policies and practices that have established institutional training as the dominant mode. They argue further that CGTU training can be more clearly individualized and performance based, thereby creating benefits in both effectiveness and real efficiency that far outweigh any presumed loss of unit readiness. Also, they point

out that there are certain aspects of training that cannot be accomplished except in the context of the operational unit (see Pridgen & Demongeot, 1965, for a discussion of the need for new approaches to weapon-system training).

The two positions outlined above give rise to two important, but as yet unanswered, research questions that have apparently not been specifically addressed in the training literature, namely: (a) to what extent is collective CGTU performance compromised by the substitution of different proportions of untrained personnel into the unit, and (b) to what extent does collective CGTU training enhance the acquisition of skill by both individual CGTU members and the group as a whole, again as a function of the team-training loads--i.e., of the proportions of trained and untrained persons in the collective CGTU-training situations?

The present study was designed to provide laboratory data from which inferences could be drawn to answer these questions, at least in a preliminary way subject to verification by subsequent field tests. The study specifically investigates the effects of team-training loads (percentages of untrained members of a crew), at levels ranging from 0 to 100 percent in 10 percent steps, on the relative efficiency of the training and performance effectiveness of the crew. The team-training load is viewed as a parameter of effectiveness for collective training in units, and the data of the present study should provide information regarding the end-point parameters--the ranges of team-training loads within which training and team performances appear to be optimal. By thus delimiting the range of viable alternative team-training loads, the data should help guide the selection of team-training loads and optimizing conditions suitable for field testing with military units.

METHOD

This investigation was identified internally as PETT (for Parameters of Effectiveness of Team Training). It was conducted in two phases (PETT-1 and PETT-2) during the summer of 1977. In

all, 10 studies were conducted, each of which involved 5 subjects working together as a crew or team for 8 hours per day over 6 consecutive days. As outlined in Table 1, these teams were composed of different combinations of the total of 20 undergraduate male volunteer subjects to provide 6 different levels of team-training loads (percentages of untrained team personnel), ranging from 0 to 100 percent in 20 percent steps. PETT-1 was conducted from 16 May 1977 through 18 June 1977, and provided data on team-training loads of 0, 20, 80, and 100 percent (untrained team members). PETT-2 was conducted from 20 June 1977 through 23 July 1977, and provided data on team-training loads of 0, 40, 60, and 100 percent. Each of the 10 teams (i.e., each combination of 5 subjects) performed the synthetic work of the Performance Assessment Laboratory's Multiple-Task Performance Battery (MTPB; see Alluisi, 1969; Chiles, Alluisi, & Adams, 1968; and Morgan & Alluisi, 1972) for 48 hours (8 hours per day over 6 successive days). The first 48 hours of a subject's performance of the MTPB tasks are considered "training," for that was the period typically required to reach trained "baseline" performance levels in prior studies (cf. Alluisi, Coates, & Morgan, 1977). All subjects subsequently performed as "trained" team members for an additional 48 hours (6 days), and half (Nos. 1-5, 11-15) did so for a third 48-hour (6-day) period. Performances subsequent to a subject's first 48 hours of training are referred to simply as "work," or as "trained performance." The studies were designed so that the efficacy of this type of team training could be assessed functionally by combining data from various studies to produce team-training loads, or percentages of untrained team personnel, ranging from 0 to 100 percent in 10 percent steps.

Subjects

The subjects in these studies were 20 male volunteers from among the undergraduate students at Old Dominion University. They ranged in age from 18 to 30 years, with a median of 21 years, They were recruited and hired to work the tasks of the MTPB for 48 hours per week for either 2 or 3 weeks (depending on team assignment,

see Table 1). Those working for 2 weeks were paid a total of $325.00, and those working for 3 weeks were paid a total of $490.00 for their participation in the experiment. Subjects in each study were tested as members of their respective crews; i.e., as one of five team members working together in the same room, each operating one of five identical MTPB panels.

Table 1. **Experimental** Schedule **and** Composition of Experimental Teams.

Phase of Experiment	Dates of Data Collection	Team Number	Subject Numbers	Training Load (Percentage Untrained)
PETT-1	16-21 May 1977	1	1,2,3,4,5	100
	23-28 May 1977	2	1,2,3,4,5	0
	30 May-4 Jun 1977	3	1,6,7,8,9	80
	6-11 Jun 1977	4	2,3,4,5,10	20
	13-18 Jun 1977	5	6,7,8,9,10	0
PETT-2	20-25 Jun 1977	6	11,12,13,14,15	100
	27 Jun-2 Jul 1977	7	11,12,13,14,15	0
	4-9 Jul 1977	8	11,12,16,17,18	60
	11-16 Jul 1977	9	13,14,15,19,20	40
	18-23 Jul 1977	10	16,17,18,19,20	0

Apparatus

The principal behavioral measures in these studies were obtained from the subjects' performances of the six tasks presented with the MTPB. The tasks were displayed on each of five identical operator panels (one for each member of the five-man crew). The front of one of these panels is shown in Figure 1.

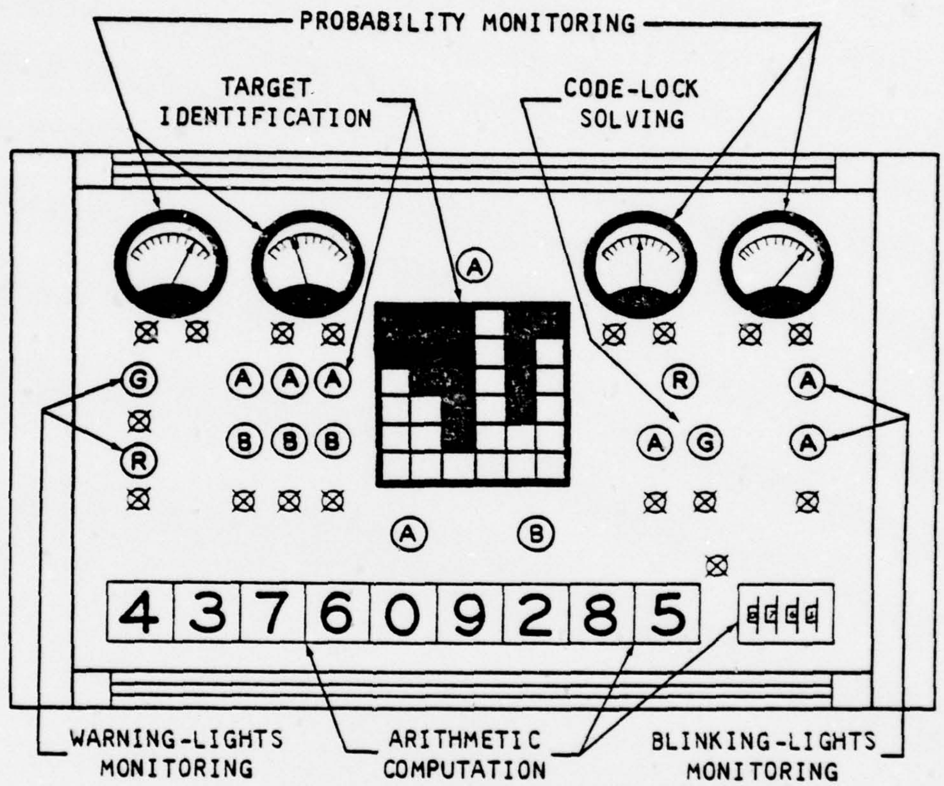

Figure 1. Schematic diagram of the front view of an MTPB operator panel. Letters in circles represent indicator lights: A -- amber, B -- blue, G -- green, and R -- red; the smaller circles with crossing diagonals represent push buttons.

Three watchkeeping tasks were used to measure each subject's performance of watchkeeping, vigilance, or attentive functions (blinking-lights, warning-lights, and probability monitoring). Three active tasks were used to measure his performance of memory functions (arithmetic computations), sensory perceptual functions (target identification), and procedural functions (code-lock solving). Since all of the tasks have been described fully in previous publications (e.g., Adams & Chiles, 1961; Alluisi, 1969; Chiles, Alluisi, & Adams, 1968; Morgan & Alluisi, 1972), they will only be briefly identified here.

The three watchkeeping tasks are performed continuously. Warning-lights monitoring requires that the subject respond to the relatively infrequent lighting of a red light or extinguishing of a green light. Blinking-lights monitoring requires that he respond to the relatively infrequent arrest of alternation of two amber indicator lights. Probability monitoring represents a watchkeeping task of a more complex nature that requires the subject to integrate over time the movements of four meter pointers, controlled by a random process, in order to detect a relatively infrequent shift in the mean value of the process (i.e., a shift in the mean pointer position from vertical to a right or left deviation equivalent to about one standard deviation unit of the random process).

Two of the three active tasks are experimenter paced. The arithmetic computations task requires that the subject add a 3-digit number to another 3-digit number and then subtract from the sum a third 3-digit number. Neither paper and pencil nor any other memory aid is permitted. This task is paced at a rate of 3 problems per minute during the 30 minutes of its presentation in each 2-hour performance period.

The target-identification task requires that each subject report his judgment as to whether the first, the second, or neither of two possibly rotated "sensed-choice" images is the same as a previously displayed nonrotated "stored-target" image. This task is paced at a rate of 2 problems per minute during the 30 minutes of its presentation in each 2-hour performance period.

The third active task is a group-performance or crew task ("code-lock solving") that is time-shared with each of the other tasks during part of the two-hour performance period; it requires the five crew members to work cooperatively in order to achieve group solutions to problems. Specifically, the task requires that subjects discover the correct sequence in which each of five buttons (one at each operator position) has to be pushed to illuminate a green light. The performance requirements of this task are quite similar to those of one configuration of the "standard group task" proposed by Zajonc (1965); according to Steiner's scheme, it would be classified as a divisible, additive, maximizing task with specified matching of individuals and subtasks (Steiner, 1972). The subjects are required to respond to this task as quickly as possible without neglecting their other concomitant duties. Thus, although not paced by the apparatus or the experimenters, neither is the task entirely unpaced for the individual crewmember, who has a "time" to respond and upon whose response the rest of the crew depends! This task is presented during 60 minutes of the 2-hour performance period; it overlaps with arithmetic computations and with target identification for 15 minutes each, and is presented "alone" (i.e., with no other active task, but only with the 3 watchkeeping tasks) during the remaining 30 minutes.

As indicated above, the subjects worked the MTPB tasks according to a basic two-hour task program. This program, which is shown in Table 2, provides scheduled periods of different relative demands on performance and was designed to be as comparable as possible to the program used in earlier studies of sustained performance with the synthetic-work methodology (cf. Alluisi, Coates, & Morgan, 1977; Beisel, Morgan, Bartelloni, Coates, De Rubertis, & Alluisi, 1974; Chiles, Alluisi, & Adams, 1968; Morgan, 1974).

As shown in Table 2, there are 30 minutes of low-demand performance, 60 minutes of intermediate-demand performance, and 30 minutes of high-demand performance during each 2-hour period of testing. From the subject's viewpoint, there is no break between

repetitions of the program from the start to the end of a testing session or "work day," since the three watchkeeping tasks are presented continuously at each work station.

Table 2. Basic 2-Hour Task-Performance Schedule.

Performance Task	15-Minute Interval in Each 2-Hour Period 1	2	3	4	5	6	7	8
Blinking-Lights Monitoring	X	X	X	X	X	X	X	X
Warning-Lights Monitoring	X	X	X	X	X	X	X	X
Probability Monitoring	X	X	X	X	X	X	X	X
Arithmetic Computations		X	X					
Code-Lock Solving			X	X	X	X		
Target Identification						X	X	
Level of Demand	Low	Med	High	Med	Med	High	Med	Low

An amber light on each panel signals that the arithmetic-computations task will begin in 30 seconds, and a second amber light provides a similar 30-second warning for target identification. In addition, the green light used with the code-lock task is illuminated 30 seconds prior to the beginning of the first problem of that task. The subjects were told that their performances were being scored continuously, as indeed they were, but analyses have been made only of the data obtained during the 90-minute intermediate-demand and high-demand performance periods in each 2-hour period of testing.

Orientation

Prior to the beginning of data collection in each of the two phases of the experiment (PETT-1 and PETT-2), the subjects were given a general orientation and briefing regarding the nature of the research project and the schedule of testing. Attention was directed to the objectives of the study and the importance of

collecting reliable data on human performance during both the training and the post-training periods of work. During the briefing session the subjects were familiarized with the MTPB tasks and given general instructions as to how to perform each task. All questions concerning task performance were answered, but no pretest practice was allowed. The subjects were also given instructions, presented as part of a standard operating procedure (SOP), concerning all other procedures related to the test conditions, including those incidental to the actual MTPB testing.

For example, the SOP covered the use of the intercom system. In general, standard radio procedures were followed. The test crew was designated with the study's code name, "PETT-1" or "PETT-2," and the experimenter station was designated with the series name and the word "control" ("PETT CONTROL"). The subjects were instructed to keep intercom conversation to a minimum, and the only calls permitted between the subjects and the experimenter-control station were "business" calls such as those required to report an apparent malfunction of the equipment. Any calls initiated by the subjects that were other than business in nature were acknowledged and then cordially, but firmly, discouraged. Whenever the experimenter-control station called the crew, the call was addressed to the crew commander; if another member of the crew was to be called, the crew commander was contacted first and his permission was requested to address the specific crewmember. The intercom system was a "common-line" or single-channel system in which all stations received all communications.

The SOP was read prior to each crew's first duty period and again after 16 hours of testing, and thereafter remained posted on the subjects' side of the door to the experimental room. The SOP, which summarized the procedures established during the orientation, included the following statement:

1. The test is made up of both individual-performance tasks (i.e., blinking-lights, warning-lights, and probability monitoring, arithmetic computations, and target identification) and a crew-performance task (code-lock solving). Each crewmember is to work alone

on the individual-performance tasks, without giving or receiving help, hints, or cues from any other crewmember. Crewmembers are expected to work together on the code-lock task; there it is expected that performance will show cooperation, coordination, and the proper exchange of all necessary information among crewmembers.

2. Should a crewmember discover a way to "beat the computer," he is not to use the "trick" if he can avoid it. Its use would serve only to invalidate the results of the test. Rather, he should notify PETT CONTROL (through the Crew Commander or directly, with permission) so that corrective action can be taken.

3. Standard radio procedures will be followed in using the intercom. Interstation conversation should be kept to a minimum.

4. All requests for relief are to be made to the Crew Commander, and then only when necessary. Relief from duty stations will be limited to the 1/2-hour, low-performance periods, and then only for emergency conditions. Verbal report to the Crew Commander will be made by intercom upon leaving the duty station and again upon return to the duty station.

5. In case of malfunction of the equipment, a report should be made to the Crew Commander or (when authorized by him) directly to PETT CONTROL.

Pretest interviews were held privately with the individual subjects in each study to provide opportunities for the expression of any anxieties concerning participation in the performance-testing aspects of their work (none was evidenced) and, further, to obtain information regarding the subject's age, marital status, etc.

General Procedure

MTPB Procedures

Each of the 5-man teams was tested within an experimental room (approximately 2.74 by 4.57 meters) in which each subject sat in a semi-enclosed booth. These booths were approximately 1-meter wide, enclosed on 3 sides with walls approximately 1.5 meters high and 1.5 meters deep. Broadband noise of approximately 70 dB in intensity was employed in the experimental room during all periods of training and testing in order to mask extraneous sounds, including the sounds made by the programming equipment.

Physical conditions in the experimental areas were arranged so that when outside the experimental-testing room the subjects interacted only with the chief experimenters who served as shift leaders throughout the testing periods. A cordial, but semiformal and business-like relation was established and maintained between the subjects and the experimenters at all times. Questions and comments were encouraged, and every attempt was made to dispel any uncertainty, doubt, or anxiety that may have developed concerning the nature of the tests and the performances required for operation of the MTPB tasks. The rapport between the experimenters and the subjects was excellent throughout all the studies.

MTPB Training and Testing

The procedures and schedules were the same for each week of MTPB training and performance testing. The team assigned to work during a given week was required to perform the tasks of the MTPB from 0800 until 1200 hours and from 1300 until 1700 hours each day, Monday through Saturday; they were provided a lunch break from 1200 until 1300 hours, during which they were free to obtain whatever type of lunch they desired, with the restriction that they were not to drink any alcoholic beverages. At the beginning of each week, the new (untrained) team members were given approximately 15 minutes of refresher instructions on the performance of the MTPB tasks. However, no practice was given until these individuals actually began to work as members of the team being tested; thus, all practice (or training) data were collected and are reported herein.

Previous research with the synthetic-work methodology had indicated that 40 to 48 hours of practice were required for subjects to learn the time-sharing needed to perform the MTPB tasks to the criterion of relatively stable (asymptotic) levels of performance (cf. Alluisi, 1969; 1972). Thus, the subjects in this experiment were considered to be in training during the first 48 hours of their MTPB performance.

RESULTS AND DISCUSSION

Since the synthetic work performed with the MTPB provides scores for five individual-performance tasks and one group-performance task (code-lock solving), it is possible to analyze the two sets of scores to provide separate indices of the effects of team-training load (a) on the average individual-skill performances within the team setting and (b) on the collective performances of the team skill. Both types of measures have been employed as indices of the performance effectiveness of the team, and the individual-performance measures have been further employed as indices of the acquisition of these skills by the teams' untrained members. In all cases, the data have been reduced and analyzed by means of a standard set of analytical procedures developed for use with the synthetic-work methodology.

Individual-Skill Performances

The five individual-performance tasks of the MTPB provide a total of 13 measures of individual performance. In the first phase of the analyses, each of these 13 measures was analyzed separately for each of the 10 teams of 5 subjects listed in Table 1. The results of these analyses, which represent the "raw" data for the major set of analyses to be reported here, are presented in Figures A-1 through A-16 of Appendix A.

The interpretation of general results is based on the use of an index of general performance that combines the 13 separate measures of performance. The data of the separate individual-performance measures are not discussed in detail here because they are not easily interpretable in terms of the overall or general performance effects; i.e., because of the manner in which the MTPB tasks are time-shared, it is possible for subjects to trade-off the performances of one task in favor of another that they may consider more important.

The index of general performance employed--the mean percentage of baseline performance--has been used in numerous prior

synthetic-work studies. In computing this index, Day 6 (the 41st through the 48th hour of performance) is defined as the baseline day for each week of testing, and the mean performance on Day 6 is computed for each subject with each of the 13 available measures of individual performance. Each score for every 2-hour period of performance is then transformed into a percentage of Day-6 performance (i.e., a percentage of baseline), and the 13 percentage-of-baseline scores of a given period are averaged for each subject. The resultant score, the mean percentage of baseline, is then analyzed and interpreted as an additional individual-performance measure. The results presented below are discussed solely in terms of this general index of performance, the mean percentage of baseline.

Average Individual Performances of Five-Man Teams

The individual performance data for the 10 teams listed in Table 1 are summarized in Figure 2[1] in terms of the mean percentage of baseline performance. Each data point represents the average performance for five subjects during the respective 2-hour performance periods (the subjects worked for four 2-hour periods each day for a total of 24 periods). The top panel of this figure presents the data for the four teams (Teams 2, 5, 7, and 10) that had no (0%) untrained team members. It is clear that these curves do not show any training effect; i.e., they have no "learning curve" component. Rather, each team's performance varies randomly around (or slightly above) 100 percent of baseline, and there appear to be no clear differences among the performance levels of the four teams. If there are any differences at all, they might be that the data of Teams 5 and 10 are somewhat more variable than those of Teams 2 and 7. An analysis of variance of these data indicated that there was no significant difference among the performances of the four crews, $\underline{F}(3,16) = 1.93$, $\underline{p} > 0.17$, although overall significant differences were found across the 24 periods of performance, $\underline{F}(23,368) = 1.99$,

[1] Figure 2 and subsequent figures are grouped for convenience at the end of this report, just prior to the appendix, on pages 37 to 48.

$\underline{p} < 0.01$, and in the interaction of periods with crews, $\underline{F}(69,368) = 1.95$, $\underline{p} < 0.01$. These significant differences no doubt reflect the variability in the data of Teams 5 and 10. The performances of these four teams will be discussed further in a later section.

In the original proposal for the current research, it was decided (an arbitrary, a priori decision) that the data of Teams 2 and 7 would be combined for comparisons with other team combinations. Since the analysis of these data indicates that there is no overall difference among the four teams, it seems appropriate to use this combination as initially planned. Therefore, for purposes of analyses and comparisons to be made later, the averaged performances of Teams 2 and 7 are taken to be typical of the zero percent-untrained teams.

The data presented in the middle panel of Figure 2 represent the teams that consisted of 20, 40, 60, and 80 percent untrained team members (Teams 4, 9, 8, and 3, respectively). These data indicate that (a) each of the team-training loads produced decrements in the average individual-skill performance, (b) at least during Day 1, the decrements were larger for the greater training loads and (c) approximately three days of training were required to completely overcome the effects of team-training load. Differences in the performances of the four teams can be seen most clearly on Day 1, particularly during the first performance period. With the exception of the performance of Team 4 (20% untrained), which was poorer than that of Team 9 (the 40% untrained team), the performance of the teams was as anticipated. However, the relatively poor performance of Team 4 suggests that the performance of the one untrained member of this team was atypically low (more will be said about the performance of this individual in the next section).

The bottom panel of Figure 2 presents the data for the two teams (Teams 1 and 6) that were completely (100%) untrained. The performance of these two teams was essentially identical throughout the six days of training. Both began performing at about 70 percent of baseline on Day 1, reached 100 percent of baseline on Day 3, and maintained this asymtotic level of performance throughout

the remainder of the study. An analysis of variance of these data indicates that the overall performance of the two teams was not significantly different, $\underline{F}$ $(1,8) = 0.21$, $\underline{p} > 0.65$. Although they did yield significant differences across periods, $\underline{F}$ $(23,184) = 38.91$, $\underline{p} < 0.01$, the interaction of crews with periods was not significant, $\underline{F}$ $(23,184) = 0.90$, $\underline{p} > 0.60$. The data of these two teams have been combined for use in the analyses discussed below.

Average Individual Performances of 10-Man Team Combinations

The data presented in Figure 2 represent only 6 levels (in 20% steps) of team-training load. In order to provide five additional levels for use in the present analyses, data of the ten basic teams represented in Figure 2 (and identified in Table 1) have been systematically combined. That is to say, the data from each of the 5-man teams have been combined with those of one or two other teams to provide summary data representing 11 different proportions (in 10% steps) of untrained team members. These team combinations and the team-training loads they represent are listed in Table 3. It should be noted that although these combinations do not represent 11 independent groups, they do permit an efficient set of comparisons--the best possible without the considerable effort and expense that would be required to collect the additional data needed for truly independent comparisons.

In order to examine the potential effect of this averaging of data on conclusions to be drawn later, the data of the team combinations representing the 20, 40, 60, and 80 percent team-training loads were compared with those of (the 5-man) teams that actually worked at those levels, Teams 4, 9, 8, and 3, respectively. These comparisons, which are presented in the 4 panels of Figure 3, indicate that conclusions based upon the 10-man team combinations might be even more representative, or "typical," than similar conclusions based upon the data of the 5-man teams! That is to say, the major effect of the averaging appears to be a reduction in the variability of the data presented.

Table 3. Combinations of Experimental Teams and Their Associated Team-Training Loads.

Combination of Teams[1]	Team-Training Load (Percentage of (Team Untrained)
2 & 7[2]	0
4 & 7	10
9 & 2	20
8 & 2	30
3 & 7	40
1 & 7[2]	50
4 & 6	60
1 & 9	70
1 & 8	80
3 & 6	90
1 & 6	100

1 Numbers refer to the "Team Numbers" identified in Table 1.

2 Other possible combinations were computed for comparison purposes and were found to be essentially identical to the combinations employed to represent the 0 percent and 50 percent team-training loads.

The only substantial difference between the performance of the combined teams and the basic 5-man teams occurs at the 20 percent team-training load (top panel of Figure 3), where the performances of Team 4 are considerably poorer during the first 3 days of training than the combined (averaged) performances of Teams 2 and 9. As indicated earlier, the performances of Team 4 are atypically low relative both to a priori expectations and the performances of the other teams. Therefore, in a sense, the combination of Teams 2 and 9 yields data that may be considered more typical of the expected effects of the 20 percent team-training load than the "raw" data of Team 4 alone.

Given that the performance of Team 4 is relatively low, a question might be raised concerning the interpretation of the results from the 10 and 60 percent team combinations that involve the data of that group (i.e., averages of Teams 4 and 7, and 4 and 6, respectively). The performances of these two team combinations might also be expected to be somewhat low. However, the third panel of Figure 3 presents a direct comparison of the combined data of Teams 4 and 6 with those of Team 8, and it is clear that these two sets of data are essentially identical. This would suggest that the 10 percent and 60 percent team combinations (at least the 60% combination) are representative of team-training load effects at these levels. It is concluded that the averaging of data in computing the team combinations (a) serves to reduce the influences of extreme performers, (b) provides a more nearly representative set of data for the 20 percent team-training load, and (c) does not invalidate the conclusions to be drawn therefrom.

The mean percentages of baseline performance for each of the 11 team-training loads (the team combinations listed in Table 3) are presented in the 10 panels of Figure 4. From top to bottom, the first 5 panels of Figure 4 present the data for the team combinations representing 10, 20, 30, 40, and 50 percent untrained team members, respectively. Similarly, the data for 60 percent untrained through 100 percent untrained are presented in the second 5 panels of Figure 4. The data for 0 percent untrained are presented in each of the panels as "control" or comparison data.

It is clear from these data that as the percentage of untrained team members is increased, the beginning (Day-1) performance of the team is lower. For example, when only one (10%) or two (20%) members of the 10-man team are untrained, the team's average performance during its first period of performance is diminished by between 5 and 8 percentage points (to between about 92 and 95% of baseline performance). However, as the percentage of untrained team members is increased to 100 percent, performance on Day 1 becomes increasingly poorer, dropping to about 80 percent of baseline performance during the first performance period when 60 percent or more of the team is untrained, and to as low as 71 percent when all team members are untrained. It appears from these data that the substitution of only one or two untrained team members into a 10-man team causes only a slight disruption of performance, but if more than 20 percent of the team's members are untrained (or in the process of being trained), the performance effectiveness of the CGTU will be substantially diminished--at least during the first of a six-day training regimen.

The apparent changes in performance across the 24 periods of training were tested by computing an overall analysis of variance with appropriate orthogonal comparisons for each of the 11 data combinations represented in Figure 4. The results of these analyses, which are summarized in Table 4, indicate that all except the 0 percent-untrained team combinations yielded significant between-periods effects across all 24 periods. Thus, it can be inferred that each of the imposed training loads caused significant disruptions in the average individual performances.

The remaining F-ratios of Table 4 show that performance over the first two days (Periods 1-8) differed significantly from the performance of the final four days (Periods 9-24) for all 11 teams, and that with the sole exception of one comparision with the 70 percent training load (which yielded a significant difference between Periods 9-16 and Periods 17-24) there were no differences among the 16 periods of the last four days of training; i.e., comparisons of Periods 9 to 16 vs. 17 to 24 (Days 3-4 vs. 5-6), Periods 9 to 12 vs. 13 to 16 (days 3 vs. 4), and Periods 17 to 20 vs. 21 to 24 (Days 5 vs. 6).

Table 4. F-Ratios from Analyses of Variance of Between-Periods Effects Computed on the Mean Percentage of Baseline Performance.

Period (and Day) Comparisons	Percentage of Team Untrained: 0	10	20	30	40	50	60	70	80	90	100
Periods 1-24[1] (Days 1-6)	1.43	1.87*	2.18*	2.88*	4.49*	6.93*	6.82*	10.61*	10.50*	20.99*	35.32*
1-8 vs. 9-24[2] (1-2 vs. 3-6)	6.96*	13.38*	28.83*	18.32*	39.01*	67.52*	45.33*	143.95*	69.07*	126.74*	234.10*
9-16 vs. 17-24[2] (3-4 vs. 5-6)	---	---	1.07	1.42	---	1.13	---	4.07*	3.33	---	1.16
9-12 vs. 13-16[2] (3 vs. 4)	---	---	---	1.72	---	---	---	---	---	1.43	---
17-20 vs. 21-24[2] (5 vs. 6)	1.64	---	---	1.69	---	---	---	---	---	---	---
1-4 vs. 5-8[2] (1 vs. 2)	---	1.44	---	6.66*	13.20*	22.02*	21.90*	30.75*	29.48*	81.53*	144.11*
1-2 vs. 3-4[2] (within Day 1)	---	---	3.13	3.43	3.70	4.69*	6.43*	17.80*	11.23*	27.40*	43.51*
1 vs. 2[2] (within Day 1)	---	---	---	---	6.91*	13.92*	6.55*	13.86*	8.23*	26.92*	53.51*
3 vs. 4[2] (within Day 1)	---	---	---	---	---	---	---	---	---	---	---
5-6 vs. 7-8[2] (within Day 2)	---	---	---	---	---	1.23	---	---	---	1.49	---
5 vs. 6[2] (within Day 2)	---	---	---	---	---	---	---	---	---	---	---
7 vs. 8[2] (within Day 2)	---	---	---	---	---	---	---	---	---	---	---
9-10 vs. 11-12[2] (within Day 3)	---	---	2.19	---	---	---	---	---	---	---	---
9 vs. 10[2] (within Day 3)	---	---	---	---	---	---	---	4.03*	---	1.28	3.33
11 vs. 12[2] (within Day 3)	---	---	---	---	1.84	---	---	---	---	---	---
Residual[3]	18.45*	7.02*	2.69*	2.03*	7.86*	11.61*	3.15*	6.01*	1.53	5.45*	4.94*

[1]df = 23,216

[2]df = 1,216

[3]df = 9,216

*$p < .05$

Comparisons across the first two days (Periods 1-4 vs. 5-8) indicated that significant changes in performance occurred with all the team-training loads from 30 through 100 percent. Furthermore, the within-day comparisons indicated that significant improvements were made across the four periods of Day 1 (Periods 1-2 vs. 3-4) with the 50 percent through the 100 percent team-training loads, and over the first two periods (Periods 1 vs. 2) with the 40 percent through the 100 percent training loads; no other systematic within-day effects were obtained. (The significant difference between Periods 9 and 10 at the 70 percent training load seems to represent a random fluctuation in performance during Period 9.)

The residual F-ratios in these analyses represent the combined sums of squares for all the additional within-day comparisons that could have been computed. Although all but one of these residuals (that for the 80% training load) were statistically significant, they are of little practical significance since the data of Figure 4 show no systematic differences among the periods of Days 4 to 6.

The results of these analyses may be interpreted to mean that the performance decrements are a direct function of the team-training loads imposed, and that subsequent improvements due to training are (in this situation) essentially complete by the end of the second day of CGTU training (by Period 8). This interpretation is consistent with the picture presented by the data of Figure 4.

An additional picture of the extent to which the team-training loads may impact CGTU performance is given in Figure 5, which is based on the data of Figure 4. Specifically, Figure 5 presents the differences between the average performances of Day 1 and Day 6 (solid line), Day 2 and Day 6 (dashed line), etc., over the 11 different team-training loads. Since these functions were obtained by subtracting the average percentage of baseline performance on Day 6 (which was 100% in each case since Day 6 was the defined baseline) from the average performance on each of the preceding days, the difference score obtained is negative whenever the

average performance for a given day is lower than the baseline value of 100 percent; it is an index of the extent to which performance was diminished on each day (relative to 100% baseline) by the team-training loads.

This treatment of the data clearly indicates that as the percentage of untrained team members is increased there is an increasingly large impact on Day 1 performance; the teams with higher training loads must improve their performance more in order to regain baseline levels of performance. The same is true with respect to the differences between Day 2 and Day 6, but these differences are not as great since most of the skill acquisition takes place on the first day (as indicated by the previous analyses of variance). By Day 3, performance in all cases had nearly reached baseline levels. Indeed, there is very little change (an average gain of approximately 2%) from Day 3 to Day 6 at any of the team-training loads; and, of course, there are no systematic differences between the performances of Days 4 and 5 and Day 6. Thus, it seems that the increasing team-training loads progressively reduced the performance effectiveness of the team in terms of the level of average performance achieved as it's members began to work together. However, the amount of training required for the team to reach an asymptotic level of performance (baseline) does not seem to be affected by training load, and all teams achieved baseline performance by the third day of training.

The effect of the team-training load on the rate of individual-skill acquisition was estimated by computing separate slope constants for the different conditions across successive two-day blocks (eight performance periods). These data are presented in Figure 6 as a function of the team-training load. It is clear that increasing the load significantly increased the slope constants obtained over the first eight periods (first two days). The slope constants for the other two blocks of periods, however, are all close to zero and show no systematic variation as a function of training load. This supports the suggestion given above that, at least in terms of individual-skill performances, the effectiveness of the team was

increasingly diminished in proportion to the team-training load, but that the rates of skill acquisition differed in a compensating manner so that all teams reached asymptotic (baseline levels of) performance by the third day of training.

Performance of Trained and Untrained Team Members

The previous section was concerned with the effects of the team-training load on the average performance of the team. It was found that the performance effectiveness of the team is reduced in direct proportion to the team-training load (i.e., to the percentage of untrained team members). This says nothing about the relative performance of the trained and untrained individuals in each team. The data presented in this section will be concerned with determining the extent to which the trained and untrained team members contribute to the observed decrements in performance effectiveness. It is expected, of course, that the performance of the untrained members will be relatively low until they have experienced some degree of training, but it is also possible that the presence of the untrained team members will cause the performance of the trained members to be diminished, at least temporarily. The data presented here test this notion.

The mean percentages of baseline performance are given in Figure 7 for the trained (solid line) and untrained (dashed line) team members of each of the 11 team combinations. These data are computed for the same individuals represented in Figure 4, but here they have been separated and averaged over the trained and untrained team members respectively. Each line, therefore, represents a different number of team members as indicated by the percentages of untrained members in the team (i.e., the team that is 10% untrained has one untrained and nine trained members, 20% untrained has two untrained and eight trained members, etc.)

It can be seen from Figure 7 that the individual-skill performances of the <u>trained</u> team members <u>were</u> <u>not</u> <u>degraded</u> by the imposition of higher team-training loads. The performances of the trained members of all teams show only minor random variations around 100 percent of baseline throughout the six days. Since the

performance of each team member on the individual-skill tasks of the MTPB is independent of the performance of other team members, and no real training role is served by the trained members in that unit (i.e., trained members do not have to instruct or otherwise contribute to the training of untrained members on the individual-performance tasks), it is not surprising to find that their performances were not adversely influenced by the presence of untrained individuals. This result should not be expected to apply, however, to situations in which team members assume active training functions.

The data of Figure 7 also indicate that the performances of the untrained team members were independent of the level of team-training load. This is to say, the acquisition curves for the various groups of untrained individuals look essentially identical--in terms of both performance levels and learning rates--regardless of the load; the data of the single untrained individual in the 10 percent untrained team constitute the only exception to this conclusion. As suggested earlier in the discussion of Team 4, the performance of this individual was significantly poorer than that of all other untrained individuals in all groups from Days 1 through 4. It also took this individual longer to achieve asymptotic levels of performance. With that sole exception, the average performances of the untrained groups during their first 2-hour performance period ranged from approximately 60 to 80 percent of baseline; the untrained members of all groups had reached 100 percent of baseline performance near the end of the third day of training.

This last point is illustrated further in Figure 8, which summarizes the data of the untrained team members previously shown in Figure 7. The data plotted here represent difference scores like those presented in Figure 5 (except, of course, that in this case the computations involve only data from untrained team members). A negative score again represents the extent to which average performance was below the baseline level of performance on Day 6.

The data of Figure 8 present a picture quite different from that of Figure 5. These data show that the untrained groups (again with the exception of the one subject in the 10% untrained group)

averaged nearly 20 percent below baseline on Day 1, approximately 5 percent below baseline on Day 2, and only 2 to 3 percent below baseline on Day 3, with no real difference on Days 4 and 5. More importantly, all the curves are essentially horizontal (beyond the 20% team-training load), indicating that both the levels of performance and the learning rates of the untrained subjects were independent of team-training loads. Thus, as far as individual-performance skills are concerned, it must be concluded that the reduction in the average performance effectiveness of the team with increasing levels of team-training loads is a linearly additive function of the number (or percentage) of untrained individuals added to the team. There seems to be no detrimental effect on the acquisition rates of the untrained individuals, nor on the individual-performance levels of the trained team members.

Team-Skill Performances

Because code-lock solving is a crew or team-performed task, it provides only group or team measures rather than scores for individual subjects. Thus, the discussion of this section is concerned with the extent to which the team members worked cooperatively in order to achieve a group solution to the code-lock problems. Performance on this task has been analyzed for each team in terms of the mean percentage of erroneous responses (i.e., responses made out of sequence), the mean time per response, and the mean number of code-lock problems solved per minute (or the relative information rate per period).

The results of a previous factor analysis (see Alluisi, Chiles, Hall, Hawkes, 1963, pp. 29-30) indicated that two multiple-group factors, speed and accuracy, could be identified in the various possible scorings of this task. The mean percentage of erroneous responses had a high negative loading on the accuracy factor, and the mean time per response had a high negative load on the speed factor. Each of the two measures had smaller loadings in the same direction on the other factor. The mean number of code-lock problems solved per minute, or its linear transform, "the relative information

rate per period," was about equally loaded on the speed and accuracy factors (+0.70 and +0.65, respectively), and so can be used as a composite measure that combines speed and accuracy. The results presented below are discussed only in terms of this measure; results obtained with the other two measures are presented in Appendix A.

In performing the code-lock solving task, the subjects were required to discover the solution to the problem presented. After a 30-second waiting period, they were then required to re-enter their solution. Previous analyses had indicated that use of the combined scores for both "first" and "second" solutions did not produce a loss of sensitivity, even though the sensitivity was expected to accompany primarily the "second" solutions (see Alluisi et al., 1963, pp. 28-29). Accordingly, the data reported here are the scores representing the composite of both solutions.

Finally, performance of the code-lock task was scored separately for each of the three response conditions--i.e., with simultaneous presentations of watchkeeping tasks only, with watchkeeping and target identification, and with watchkeeping and arithmetic computations. Data from each of these scorings with each of the three performance measures have been analyzed and are presented in Appendix A for each team of subjects. However, only the performances with watchkeeping and arithmetic computations are presented here, primarily because the sensitivity of the task appears to be greatest under this highest of workload conditions. Thus, data representing the mean number of code-lock problems solved per minute (or the relative information rate per period) during concurrent performance of the watchkeeping and arithmetic-computation tasks are presented in Figure 9.

The data presented in the 10 panels of Figure 9 represent the same team combinations as those presented in Figure 4. In the present case, however, the data are averaged over two teams rather than over 10 individual subjects; in addition, these data have not been converted to a percentage of baseline. As a result, the code-lock data appear to be somewhat more variable than the individual-performance data. For example, the data for the 0 percent untrained

condition, which is presented in each panel for comparison purposes, fluctuate between approximately 1.15 and 1.35, with an average of between 1.20 and 1.30 solutions per minute. In spite of this inherent variability in these data, it is clear from Figure 9 that increases in the team-training load produced larger and larger impacts upon team performance. As was the case with the individual-performance measure, the decrement during the first day of team performance was relatively small when only 10 to 20 percent of the team was untrained (with performance remaining above 1.10 solutions per minute). However, as the percentage of untrained team members increased, the performances of the teams decreased to nearly 0.60 solutions per minute when 100 percent of the team were untrained.

These data were analyzed further by computing the difference scores presented in Figure 10. These data represent the average performance on Day 6 subtracted from the average performance for Day 1, Day 2, etc., divided by the average performance for Day 6 and multiplied by 100 to transform the differences to percentages of Day-6 levels. These data indicate that team performance was influenced by the team-training load only on Day 1; the level of Day 1 performance was progressively poorer as a function of increasing team-training loads. With the exception of the 10 percent training load (which, it should be recalled, had only 1 untrained team member, and his individual-skill performance was atypically low), the effect of training load was relatively minor at training loads below 40 percent. However, these data show that team performance on Day 1 was considerably below the level of Day 6 performance at training loads of 40 percent or higher. Thus, it must be concluded that increasing the team-training load decreases performance effectiveness in terms of team-skill as well as individual-skill performances. The decrements in the case of the team-skill performances appear to be more sensitive to a "critical-mass" factor--more than 40 percent untrained is substantially worse than fewer than 40 percent untrained in terms of team-performance criteria.

The data of Figure 10 indicate that there were no systematic differences between Day 6 performance and the average performance on Days 2 through 5. This suggests that the acquisition of the team-performance skill was completed by the end of Day 1 or very early in Day 2. The data of Figure 9 confirm this suggestion, showing that all teams reached asymptotic levels of performance by the first or second period of Day 2. Thus, the team-skill performances were learned much more quickly than were the individual performances (which did not asymptote until Day 3). However, as was the case with the individual-skill performances, the acquisition rate for the team skills was independent of the team-training load. That is to say, even though the higher team-training loads caused greater decrements in Day-1 performances, all of the teams were able to overcome the effects and reach asymptotic performance by Day 2. Learning rates in terms of both team- and individual-skills acquisition are compensatingly greater with the higher team-training loads, so that both individual and team skills are acquired in a constant training time, regardless of the team-training load.

Fully Trained Team Performances

The analyses presented in the two previous sections indicate that the performance, but not the training, effectiveness of teams is diminished by increasing levels of team-training load. These findings apply primarily to the teams' designated periods of training, i.e., their first 48 hours of performance on the MTPB tasks. However, certain of the reported data have important implications for operational situations that go beyond the period of training *per se*. Specifically, the data presented in the top panel of Figure 2 may be interpreted in terms of their implications concerning the post-training performance of teams whose members have been trained in different units with different training loads.

The question of primary concern is the following: What are the effects of assigning different percentages of fully trained individuals from *other* teams on a team's post-training performance

effectiveness? In other words, if individuals who are trained within units that have different proportions of untrained personnel are transferred from their training units to form a new operational unit (or into an existing operational unit), will the performance of this "new" unit (consisting of individuals who were trained in different settings) differ from that of a unit whose members have been together throughout training (consisting of individuals who were trained as a team in a single setting)? In terms of the current studies, for example, will the performance of a unit (e.g., Team 5) consisting of four individuals who were trained within one team (e.g., Team 3, with an 80% team-training load) and one who was trained within another team (e.g., Team 4, with a 20% training load) differ from that of a unit (e.g., Team 10) consisting of three persons who were trained in one team (e.g., Team 8, with a 60% training load) and two who were trained in another team (e.g., Team 9, with a 40% training load), or from a unit (e.g., Teams 2 and 7) whose members were all trained together (e.g., Teams 1 and 6, with a 100% training load)?

As discussed previously, the data presented in the top panel of Figure 2 indicate that the performance of a fully trained team is independent of the training-load context in which the members of that team were trained. An analysis of variance of the data from Teams 2, 5, 7, and 10 indicated that there was no significant difference among the performances of these four teams. Thus, it appears that beyond the period of training, there is no advantage in requiring the individuals who make up an operational unit to be trained together prior to operational assignment, nor is there any disadvantage. Thus, individuals (and teams) may be trained collectively in a unit whose sole mission is training, then transferred to work as part of another team (or unit) without loss of performance effectiveness. Since the results of this study indicate that teams with 100 percent team-training loads reached asymptotic performance with the same amount of training as teams with lower training loads, it would seem that greater efficiency would accrue from providing collective training within training units prior to operational assignments.

CONCLUSIONS AND RECOMMENDATIONS

The effects of the team-training load (i.e., the percentage of untrained members in a team) on the performance effectiveness of the team and on the acquisition of both individual skills by the untrained members and team skills by the teams were investigated. Eleven team-training loads ranging from 0 to 100 percent in 10 percent steps were represented by different combinations of data from 5-person teams containing from zero to five untrained persons (0 to 100% in 20% steps). The Multiple-Task Performance Battery (MTPB) of the synthetic-work methodology provided the job on which the teams and their members were trained or performed over six successive days, eight hours per day. Performances were assessed in terms of both average individual performances (an index of general performance based on 13 measures of five individual-performance tasks) and of average team performances (on a crew or group-performance task). The findings, and conclusions based on these, are as follows:

(a) The performance effectiveness of a team is degraded in direct proportion to the team-training load--i.e., to the percentage of untrained members assigned to the team.

(b) The decrement results from the poorer performances of the untrained individuals, and does not adversely affect the higher levels of performances of the trained team members.

(c) The untrained team members tend to acquire the individual-performance skills at the same rate, independent of the team-training load, so that all teams reach the baseline (asymptotic) levels of performance at the same time. In other words, teams with high team-training loads initially suffered greater decrements in performance effectiveness, but recovered in the same training time as teams with lower team-training loads, thereby giving the impression of a greater rate of recovery--this being a result of the greater number of individuals

improving (because they were initially untrained), but doing so at essentially constant rates.

(d) Results were essentially identical for performances measured in terms of either individual-skill or team-skill performances, with some relatively minor exceptions: (1) the team-skill performances are more resistant to decrements with the lower team-training loads (below 40% untrained), but then are more seriously affected by higher team-training loads (above 40% untrained), relative the average individual-skill performance, and (2) the latter, the average individual-skill performances, are relatively unaffected by the lowest levels of team-training loads (10%, possibly to as high as 20%, untrained).

These results obtained in a laboratory study with a task that has been used successfully in the past to assess the effects of various stressful conditions on operator performances in man-machine system settings need now to be verified in the field with tasks that are representative of CGTU duties in the combat arms. If the results are replicated, the implications for the maintenance of operational combat readiness (CGTU performance effectiveness) in the presence of personnel turbulence and turnover are clear: (a) if fewer than 10% of the CGTU's are untrained, then the best strategy would be to assign the untrained persons uniformly throughout so as to minimize the proportion of untrained personnel in any one CGTU, following the best available schedule for collective training in the units. On the other hand, (b) if the personnel turbulence and turnover between unit training opportunities is greater than 40%, then the best strategy (and probably the most cost-effective) is to assign maximum numbers of untrained members to certain teams and to schedule those teams for earlier team-training missions even at the expense of postponing the training of the CGTU's that have been maintained with fully trained personnel, some of whom have been transferred from CGTU's that are assigned high percentages of untrained individuals.

Field testing, with verification or modification (as indicated), is recommended; the implications of these findings for application should be considered "suggestive" only, at least until such time as the findings of field studies can be employed to derive better estimates of the team-training load as a parameter of effectiveness for collective training in units!

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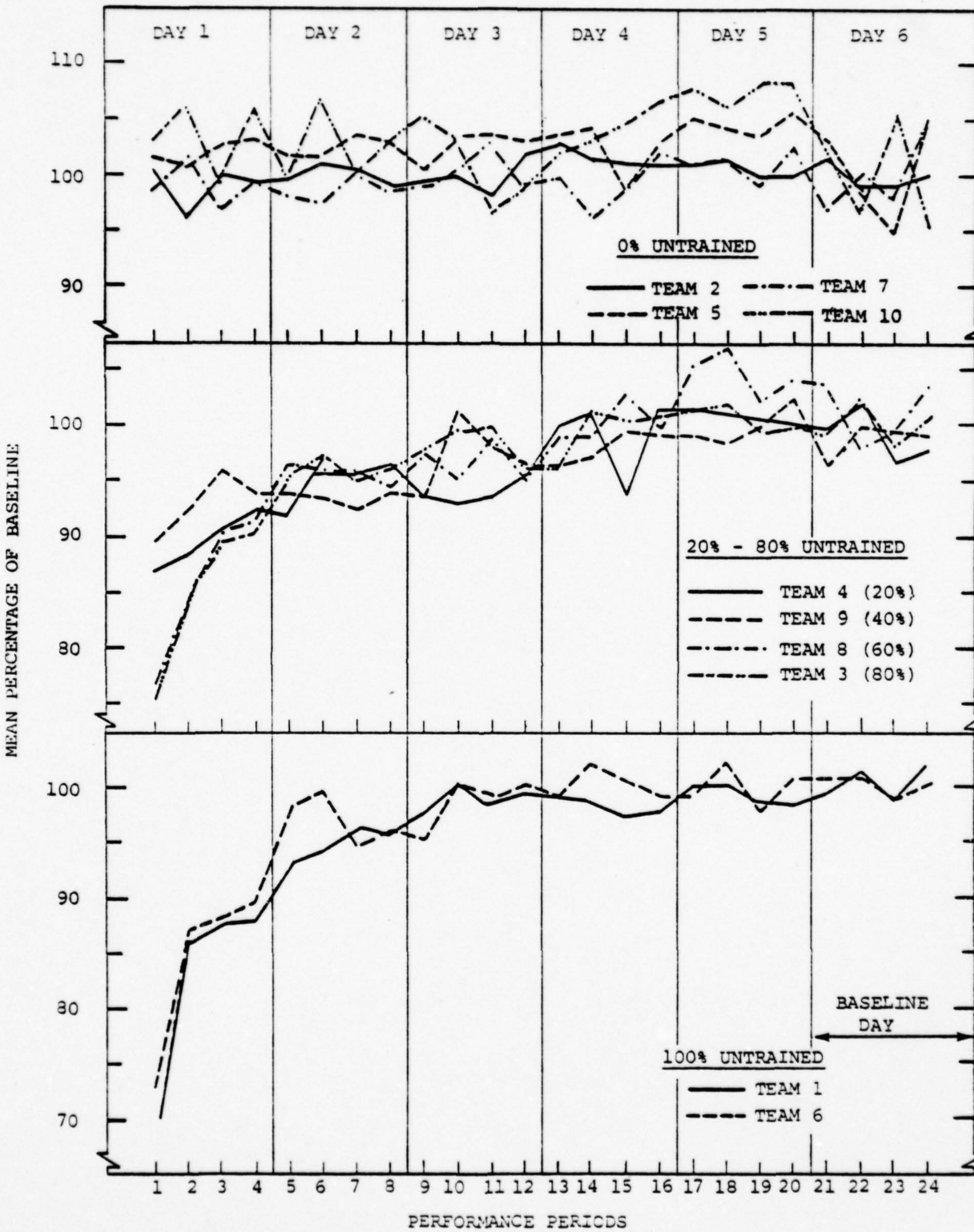

Figure 2. Mean percentage of baseline performance for each of 10 basic 5-man teams (representing 6 team-training loads) during 6 days of training.

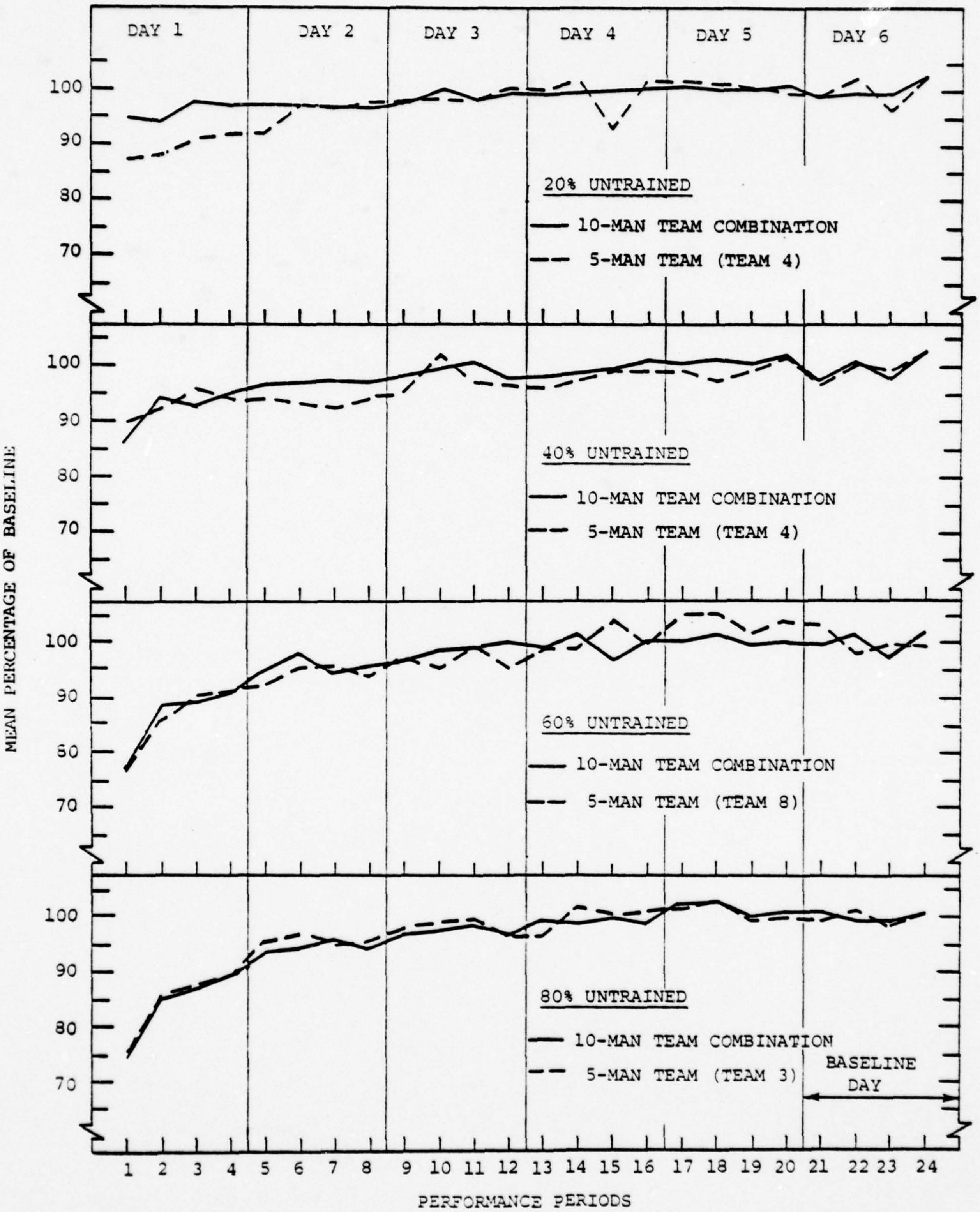

Figure 3. Comparisons of mean percentages of baseline performance for the 5-man team and 10-man team combinations representing 20%, 40%, 60%, and 80% team-training loads over 6 days of training.

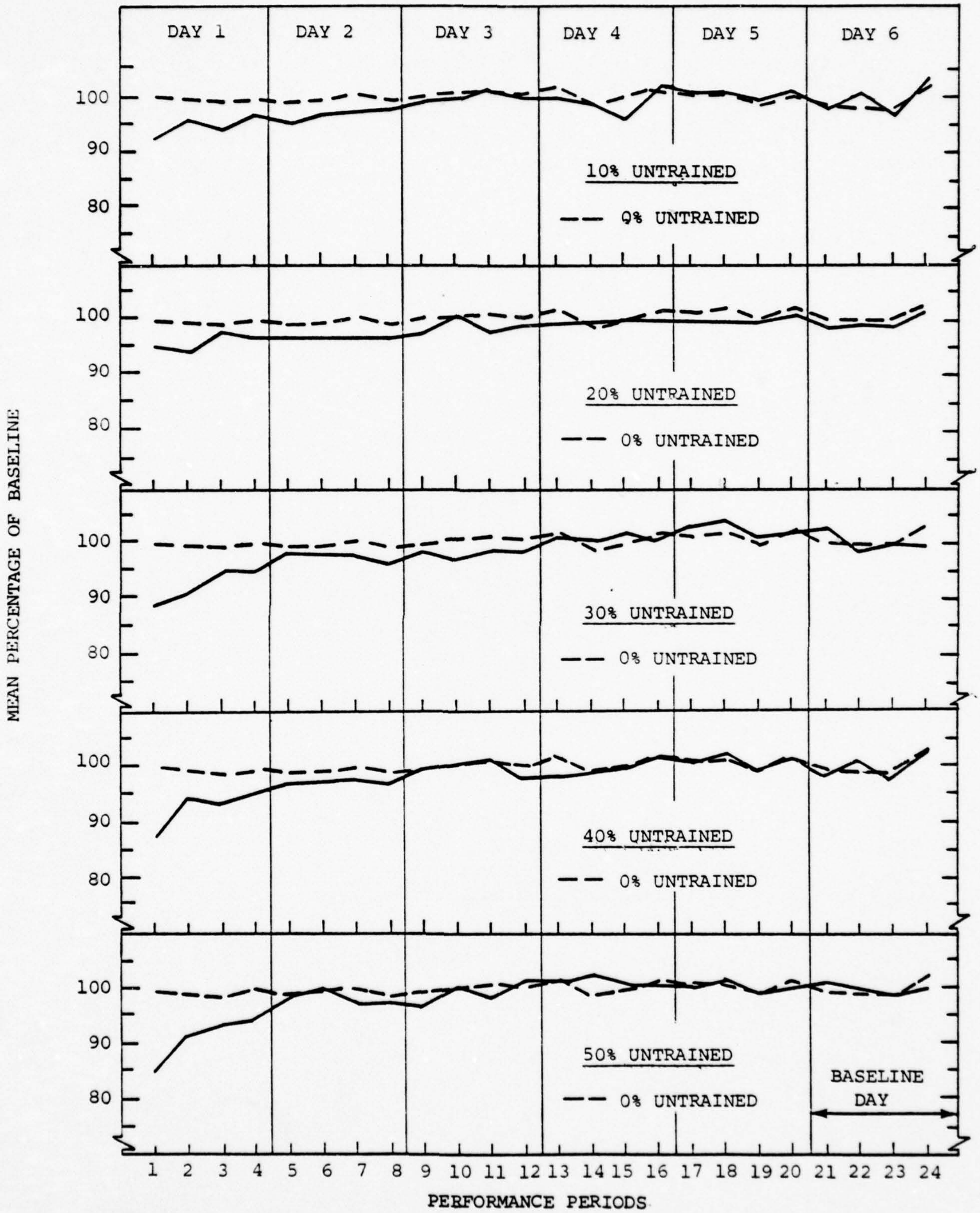

Figure 4. Mean percentage of baseline performance for 10-man team combinations representing 11 team-training loads during 6 days of training. (Continued)

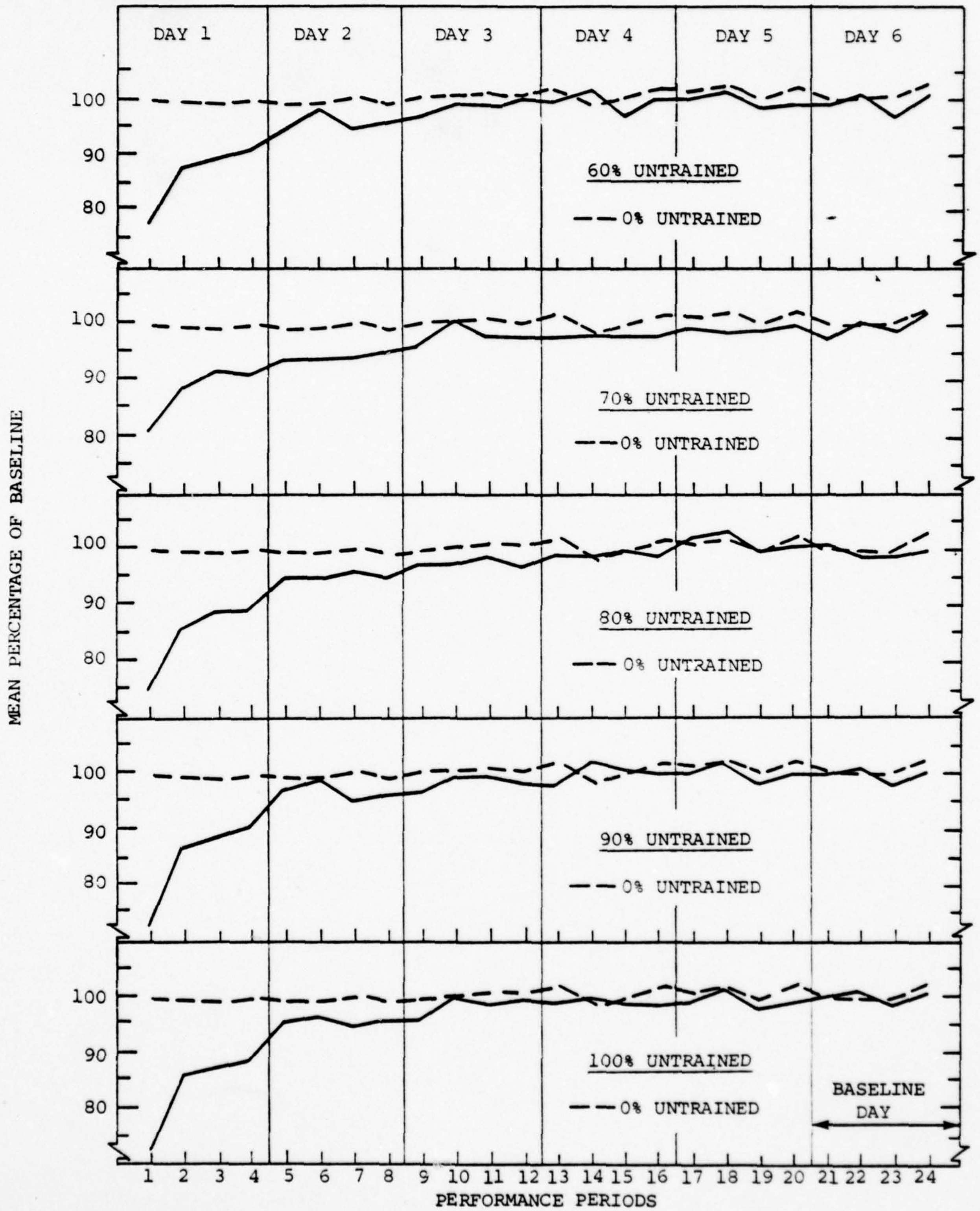

Figure 4. Concluded.

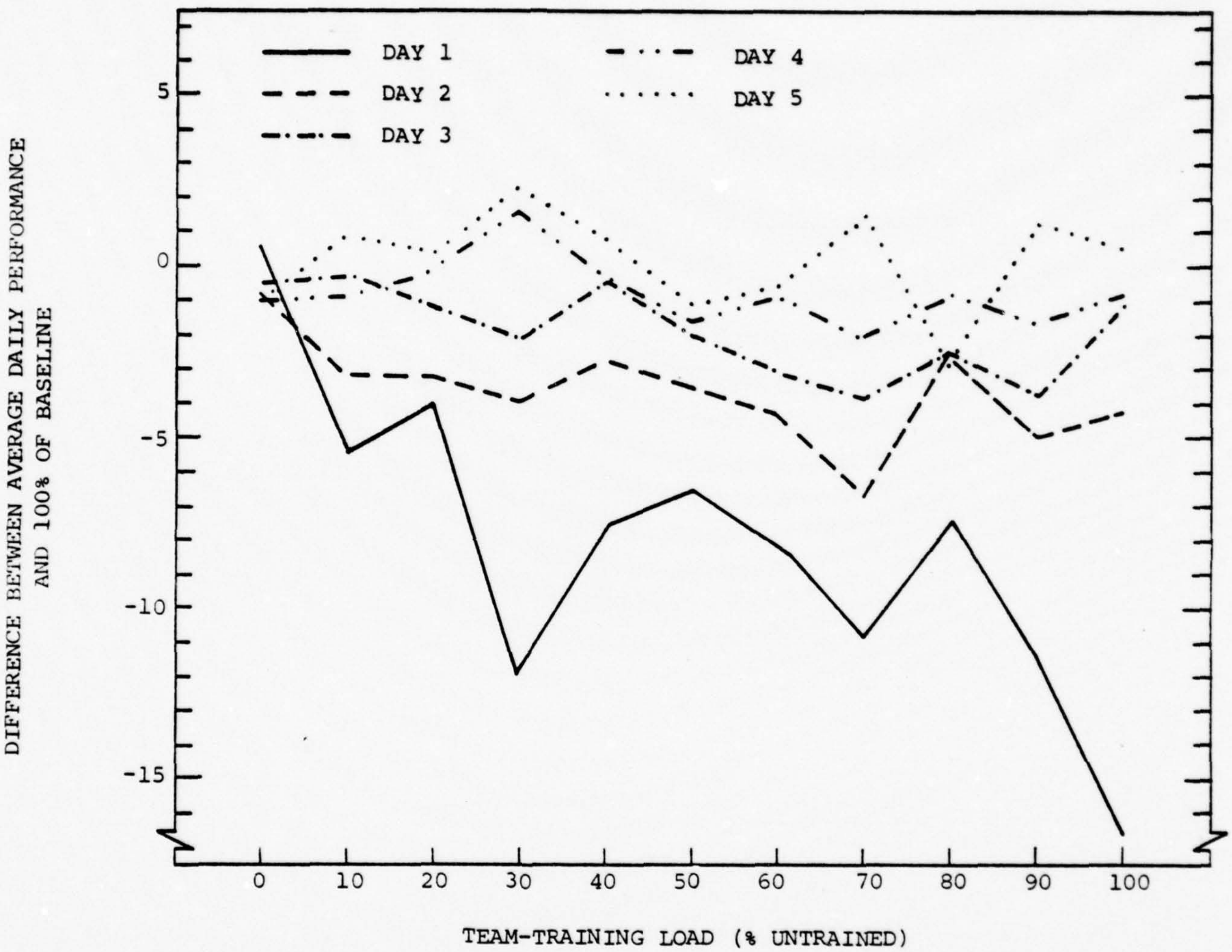

Figure 5. Differences between average individual-skill performance on the day indicated (i.e., Day 1, Day 2, etc.) and Day 6, as a function of team-training load.

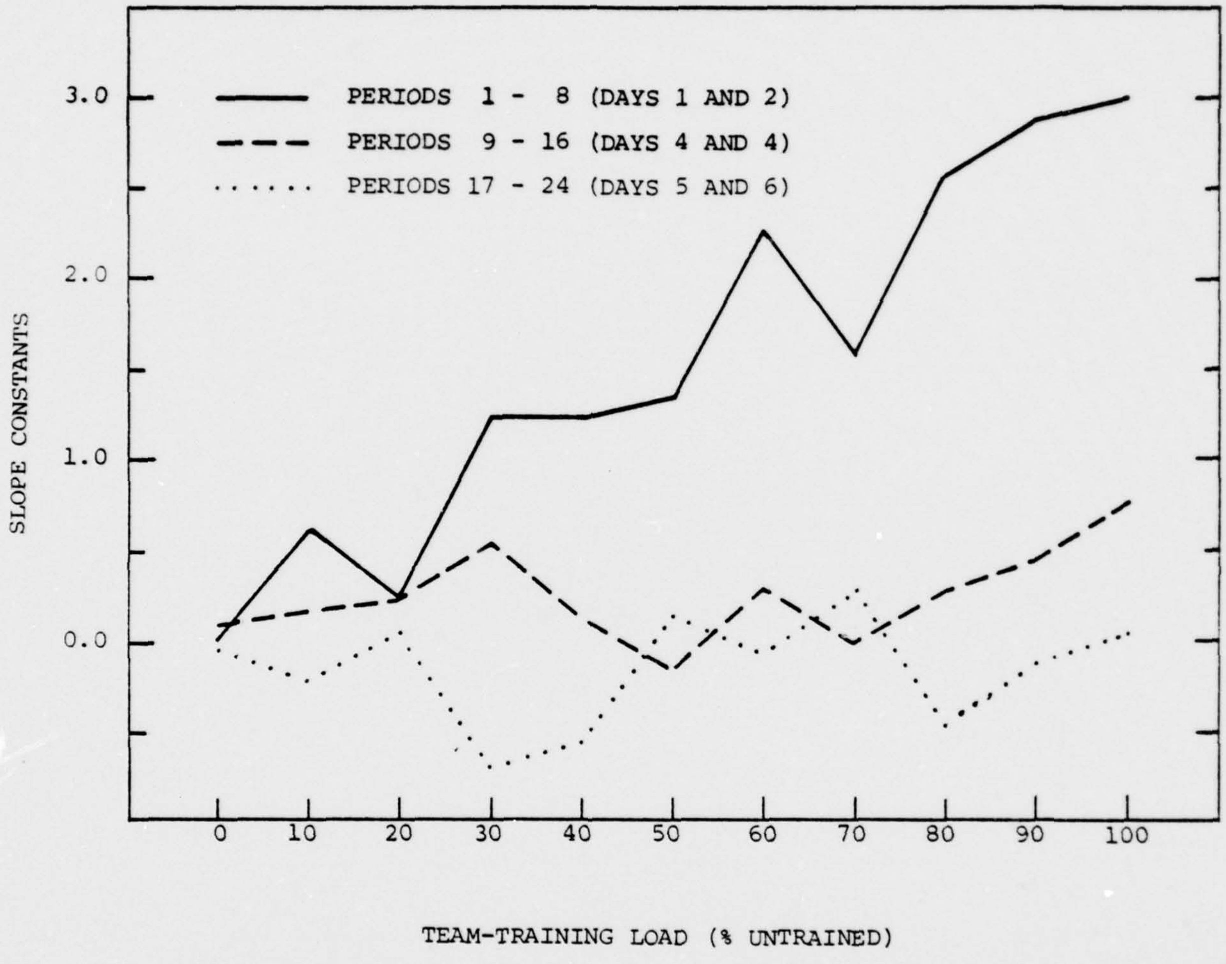

Figure 6. Slope constants, computed as the regression of mean percentage of baseline performance over successive blocks of eight training periods, plotted as a function of team-training load.

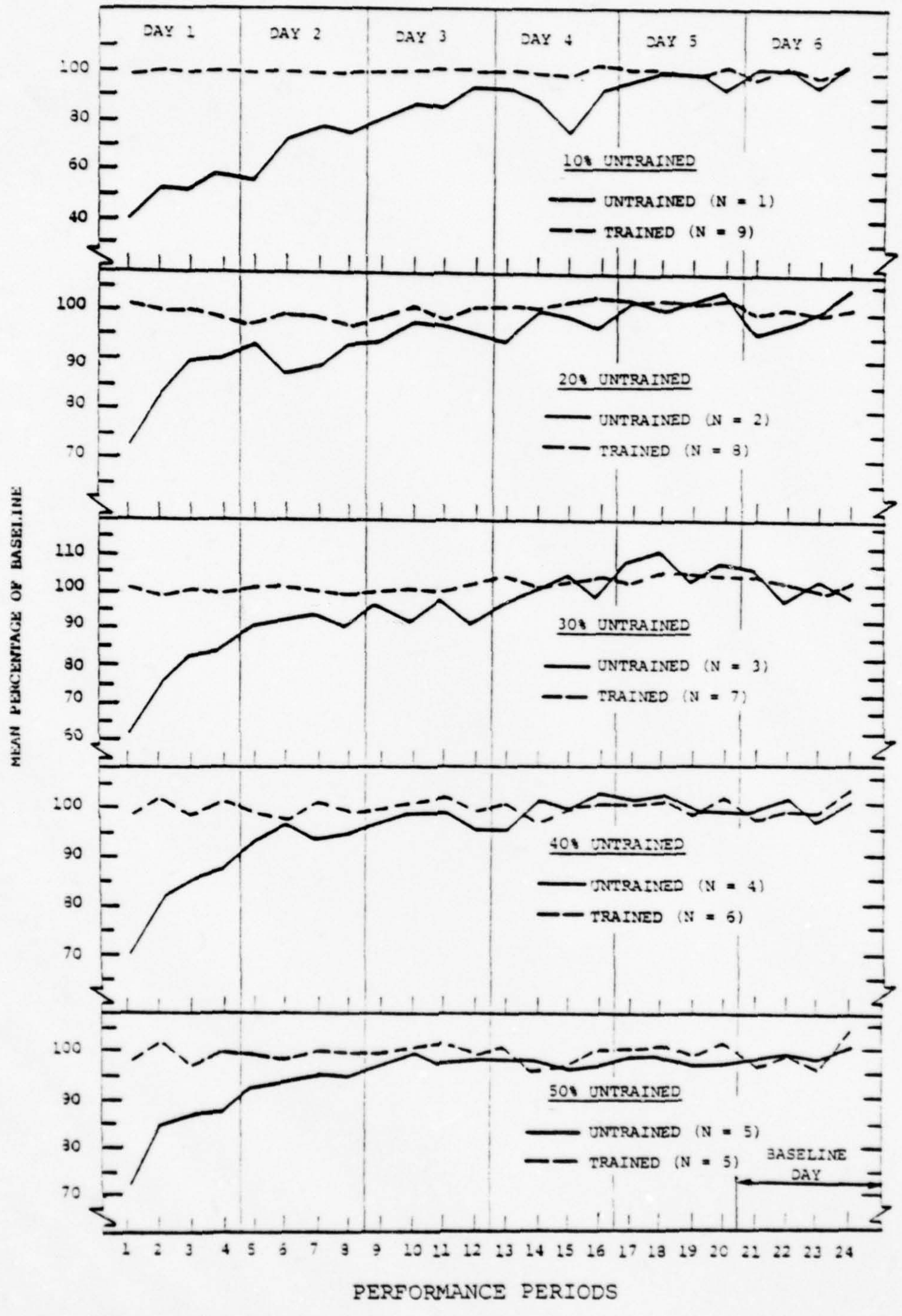

Figure 7. Mean percentage of baseline performance averaged separately for the trained and untrained individuals within each team-training load during each of the 6 days of training. (Continued).

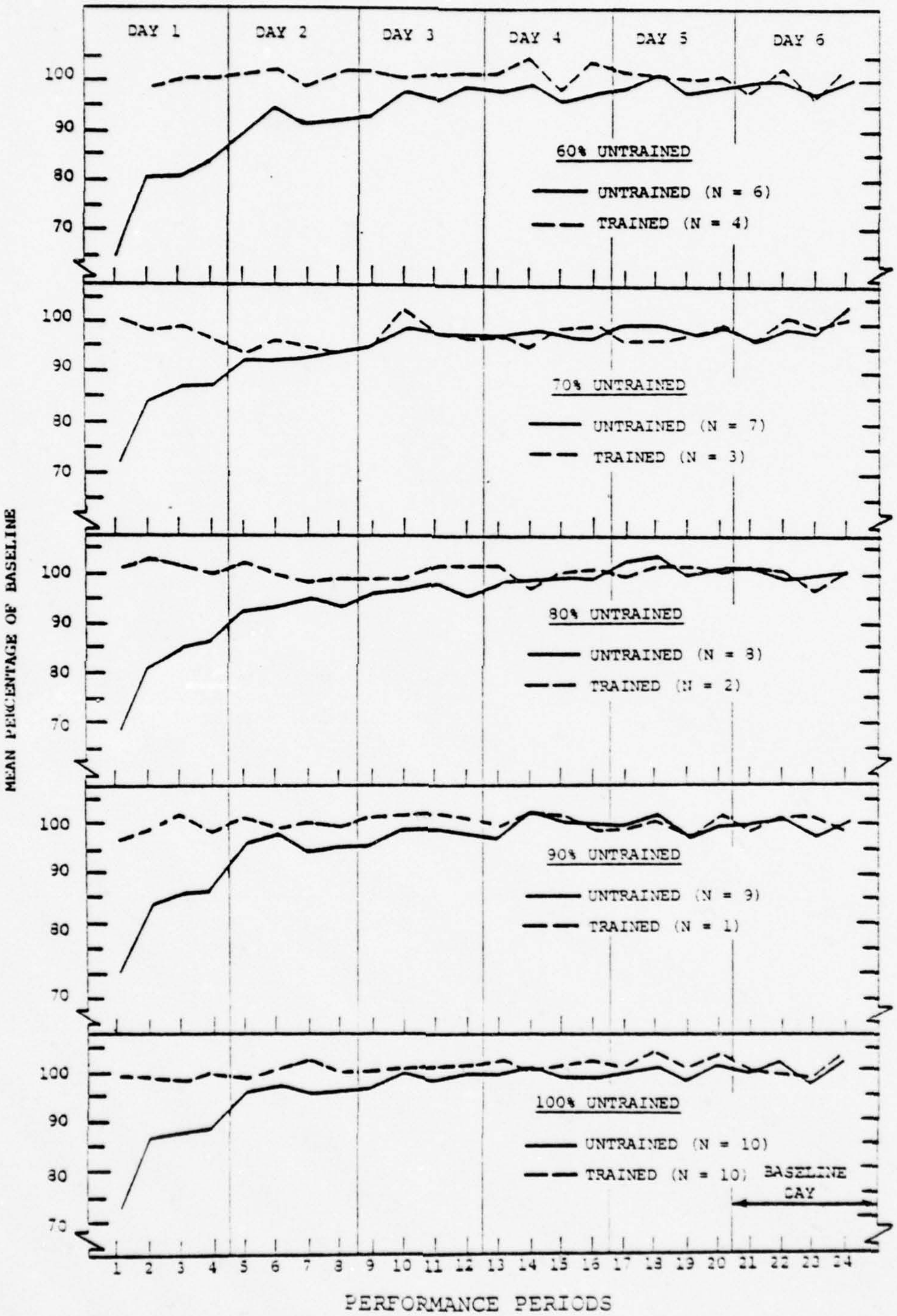

Figure 7. Concluded.

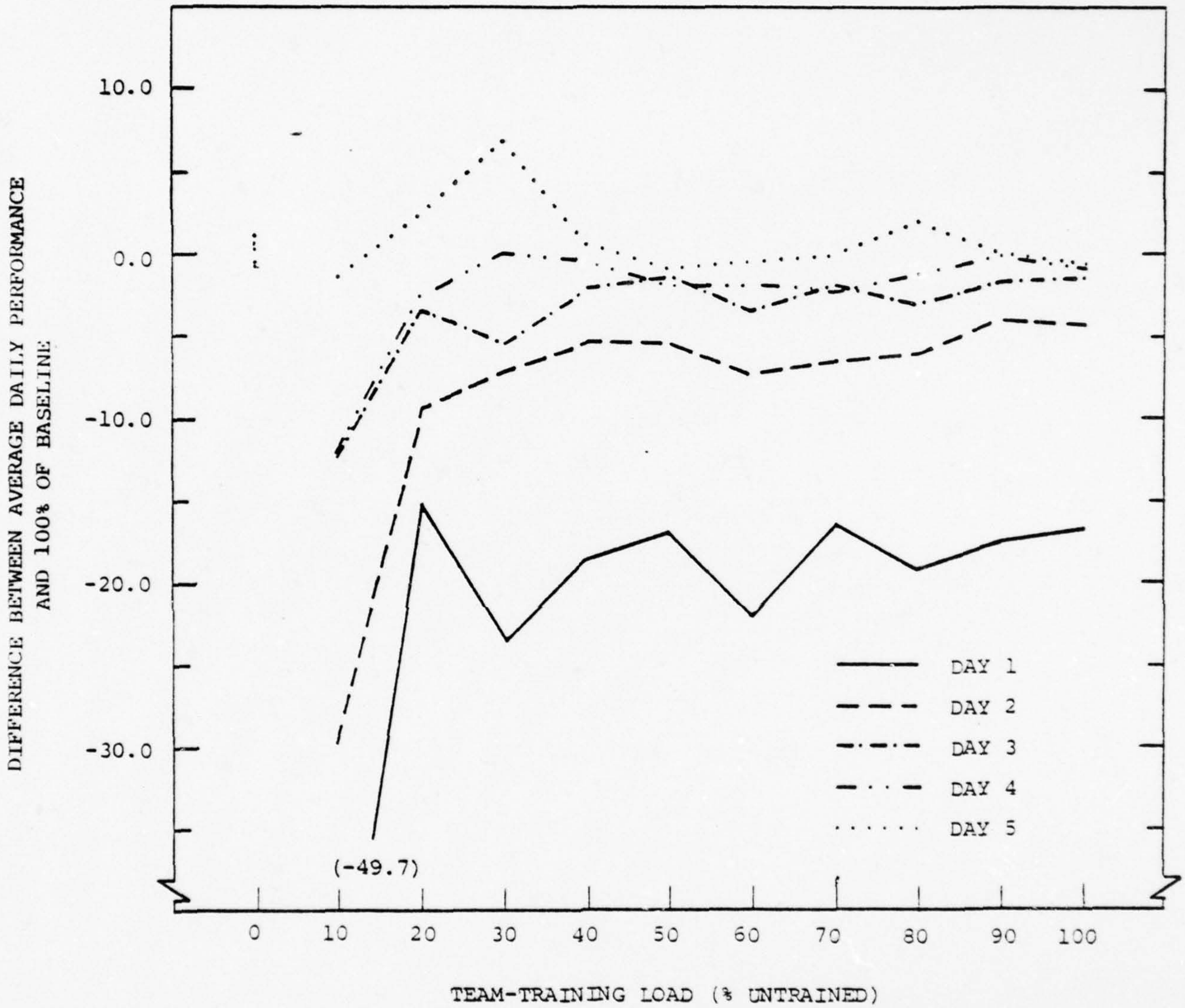

Figure 8. Differences between average individual-skill performance of the untrained subjects on the day indicated (i.e. Day 1, Day 2, etc.) and Day 6 as a function of team-training load.

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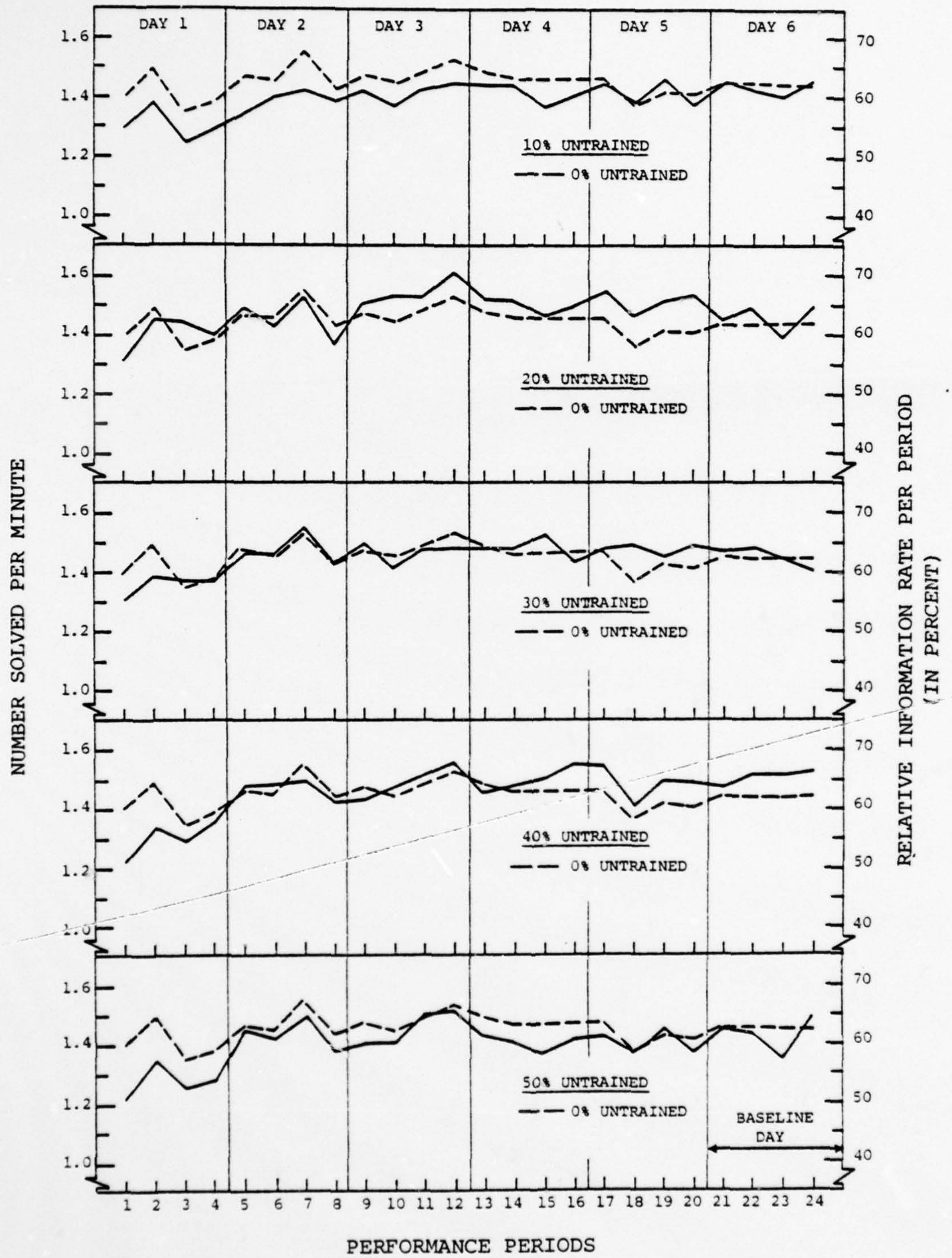

Figure 9. Mean number of code-lock problems solved per minute (left scale) and relative rate of information transmission per period (right scale) with concurrent performance of watchkeeping and arithmetic computations for 10-man team combinations representing 11 team-training loads during 6 days of training. (Continued)

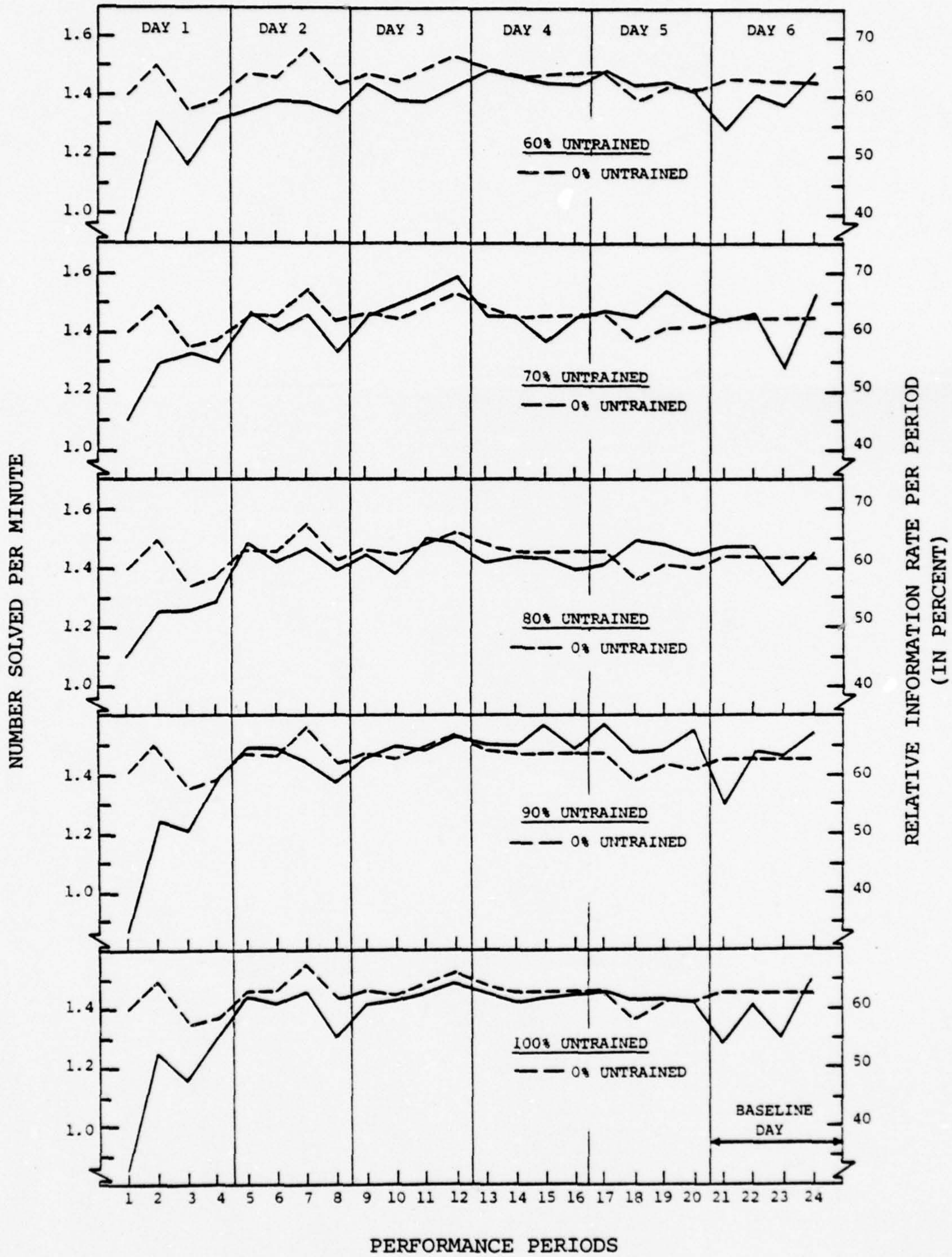

Figure 9. Concluded.

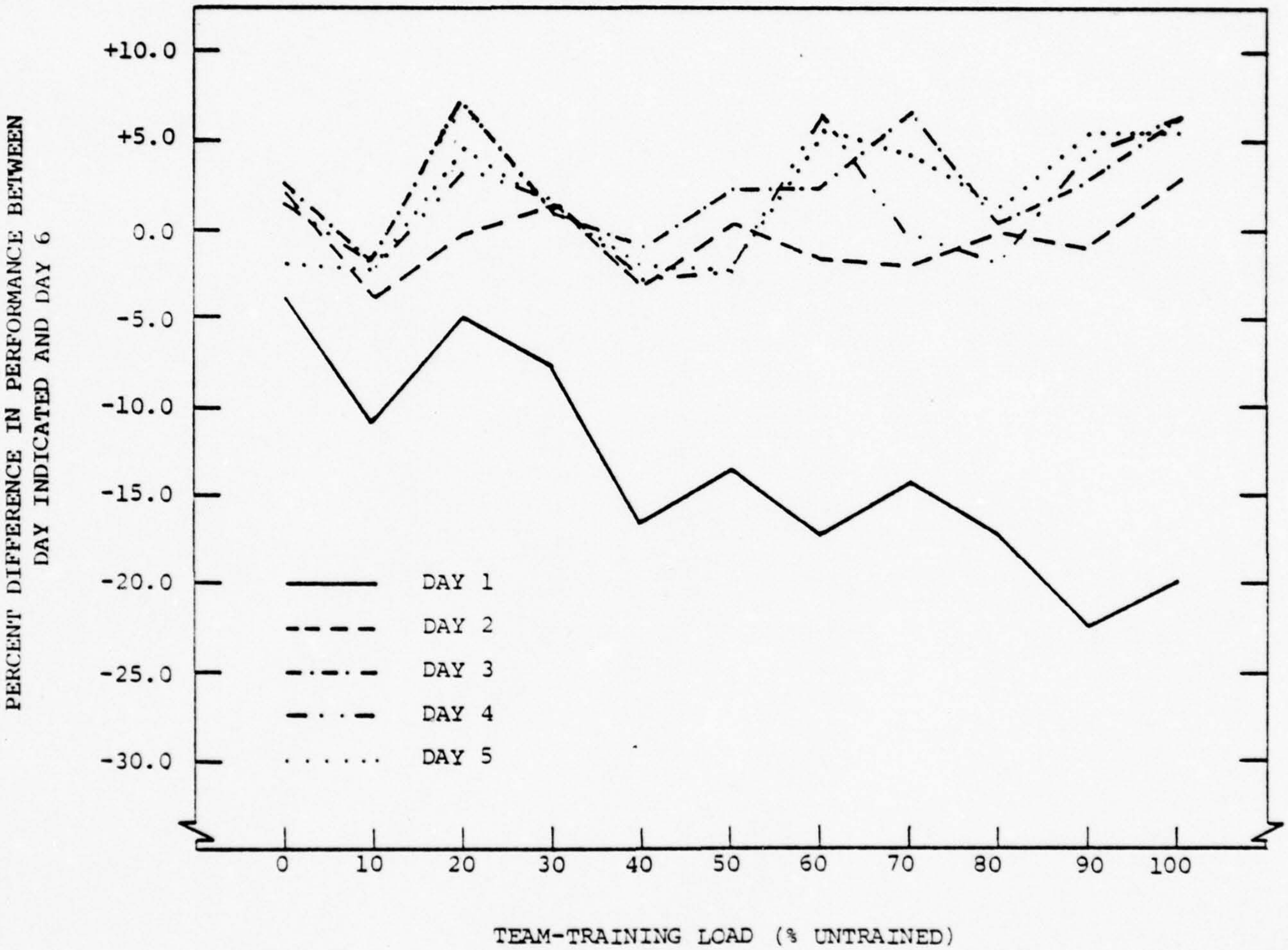

Figure 10. Mean percentage differences between average code-lock performance on the day indicated (i.e., Day 1, Day 2, etc.) and average performance on Day 6 as a function of team-training load.

Appendix A

APPENDIX A

DETAILED ANALYSIS OF INDIVIDUAL-AND TEAM-SKILL PERFORMANCES

Prepared By Curtis E. Sandler and Ben B. Morgan, Jr.

The Multiple-Task Performance Battery (MTPB) employed in this research is composed of five individual-performance tasks and one team-performance task. The five individual-skill tasks (warning-lights, blinking-lights, probability monitoring, arithmetic computations, and target identification) provide a total of 13 measures of individual performance, and the team-skill task (code-lock solving) provides three measures of group or team performance. The purpose of this appendix is to present graphically the results obtained with each of these measures for each of the 10, 5-man teams representing training loads of 0, 20, 40, 60, 80, and 100% untrained team members. That is to say, the performances of the basic 5-man teams identified in Table 1 (page 5) of this report were analyzed separately in terms of each of the possible individual- and team-performance scores. These data are presented in the figures of this appendix.

Specifically, Figures A-1 through A-13 present the basic data of the warning-lights (Figures A-1 and A-2), blinking-lights (Figure A-3), probability monitoring (Figures A-4 and A-5), arithmetic computations (Figures A-6 through A-9), and target identification (Figures A-10 through A-13) tasks. In addition, Figure A-14 presents data that represents the combined performances of the three "passive" tasks of the MTPB (i.e., this mean percentage of passive-task performance represents an averaging of the five measures of performance on the warning-lights, blinking-lights and probability monitoring tasks); Figure A-15 represents the combined performances of the two "active" individual-performance tasks (i.e., representing an averaging of the eight measures of performance on the arithmetic computations and target identification tasks); and Figure A-16 presents the mean percentage of baseline performance that represents the combined performance of all the individual-performance tasks (these data are the same as those presented in Figure 2, page 37).

In computing the data of these figures, Day 6 (the 41st through the 48th hour of performance) was defined as the baseline day for each week of testing, and the mean performance on Day 6 was computed for each subject with each of the 13 measures of individual performance. For each of the 13 performance measures, the scores for every 2-hour period of performance were transformed into a percentage of Day-6 performance (i.e., a percentage of baseline), and the 13 percentage-of-baseline scores of a given period were averaged over the five subjects in a given team. These 13 percentage-of-baseline scores are the data presented in Figures A-1 through A-13; in these figures, each data point represents the average performance of the five subjects of a given team during the respective 2-hour performance periods, expressed as a percentage of average performance on Day 6 with that measure. The data of Figures A-14 through A-16 represent a further averaging of the percentage-of-baseline scores across the five passive-task scores, the eight active-task scores, and all 13 performance scores, respectively. The top panels of these figures present the data of the four teams that had no (0%) untrained team members (Teams 2, 5, 7, and 10); the middle panels present the data of the four teams that contained 1 (20%), 2 (40%), 3 (60%), and 4 (80%) untrained team members (Teams 4, 9, 8, and 3, respectively); and the bottom panels present the data of the two teams that were completely (100%; i.e., all teams members were) untrained (Teams 1 and 6).

Data representing the performances obtained with the team-performance task are presented in Figures A-17 through A-25. As indicated in the body of this report (see pages 25 and 26), the performance of each team on the code-lock task was scored in terms of three measures of team performance (mean percentage of erroneous responses, mean time per response, and mean number of problems solved per minute), each of which was analyzed separately for each of three response conditions (with simultaneous presentations of the watchkeeping tasks only, with watchkeeping and target identifications, and with watchkeeping and arithmetic computations). Figures A-17 through A-25 present the data from each of these response conditions with each of the three performance measures: Figures A-17 through A-19 present the mean percentage of erroneous responses (i.e., responses out of sequence) for the three response conditions, respectively; Figures A-20 through A-22 present the mean time per response for each response condition, respectively;

Figures A-23 through A-25 present the mean number of code-lock problems solved per minute (or its linear transform, the relative information rate per period) for each response condition, respectively. The performances of each of the 5-man teams are presented in each figure in the same three-panel format used with the individual-performance measures.

An examination of Figures A-1 through A-25 indicates that the data presented in these figures represent different degrees of performance variability as well as differential sensitivities to the effect of team-training load. For example, performances on the three passive individual-performance tasks tended to be more variable than those of the active tasks (compare Figures A-14 and A-15). It also appears that the measures of passive-task performance were somewhat less sensitive than the measures of active-task performance. For example, the mean percentage of baseline performance of Team 3 on the combined active tasks (Figure A-15; middle panel) was approximately 68% during that team's first performance period. Their mean percentage of baseline performance on the combined passive tasks was diminished only to about 84% of baseline (Figure A-14; middle panel) during the same period of performance. Similar differences also occurred with four of the other five teams that experienced a training load (this difference was not obtained with Team 6). Given their inherent levels of variability, it is rather difficult to discern the effects of team-training load with certain of the measures of passive-task performance (cf. Figures A-4 and A-5); on the other hand, these effects are more pronounced in the data from the active tasks (an exception might be the percentage of target identification problems attempted during code-lock; i.e., Figure A-10).

A similar observation might be made with respect to the several team-performance measures. Team differences are clearly evidenced in terms of the time per response (Figures A-20 through A-22) and the number of problems solved per minute (Figures A-23 through A-25). These two measures (especially the latter one) indicate that team-training load is a significant determiner of team performance, particularly as it relates to the speed with which the team coordinates it activities in order to achieve a team performance goal. Team differences are not evidenced, however, in terms of the mean percentage of erroneous responses on the code-lock task (see Figures A-17 through A-19). That is to say, team-training load did not affect the accuracy with which the teams performed the code-lock task in this series of studies.

In addition to the observations made above, the data presented in this appendix generally support the conclusions reached in the body of this report, namely, that (a) the performance effectiveness of a team is degraded in direct proportion to the team-training load--i.e., the percentage of untrained members assigned to the team; (b) this decrement is caused by the poorer performances of the untrained individuals, and team-training load does not adversely affect the higher levels of performances of the trained team members; (c) the untrained team members tend to acquire the individual-performance skills with the same amount of training, independent of the team-training load, so that all teams reach the baseline (asymptotic) levels of performance at the same time. In other words, teams with high team-training loads initially suffer decrements in performance effectiveness, but recover in the same training time as teams with lower team-training loads, thereby giving the impression of a greater rate of recovery--this being a result of the greater number of individuals improving (because they were initially untrained), but doing so at essentially constant rates; (d) results are essentially identical for performances measured in terms of either individual-skill or team-skill performances, with some relatively minor exceptions: (1) the team-skill performances (at least in terms of the number of problems solved per minute) are more resistant to decrements with the lower team-training loads (below 40% untrained), but then are more seriously affected by higher team-training loads (above 40% untrained), relative to the average individual-skill performance, and (2) the latter, the average individual-skill performances, are relatively unaffected by the lowest levels of team-training loads (10%, possible to as high as 20%, untrained).

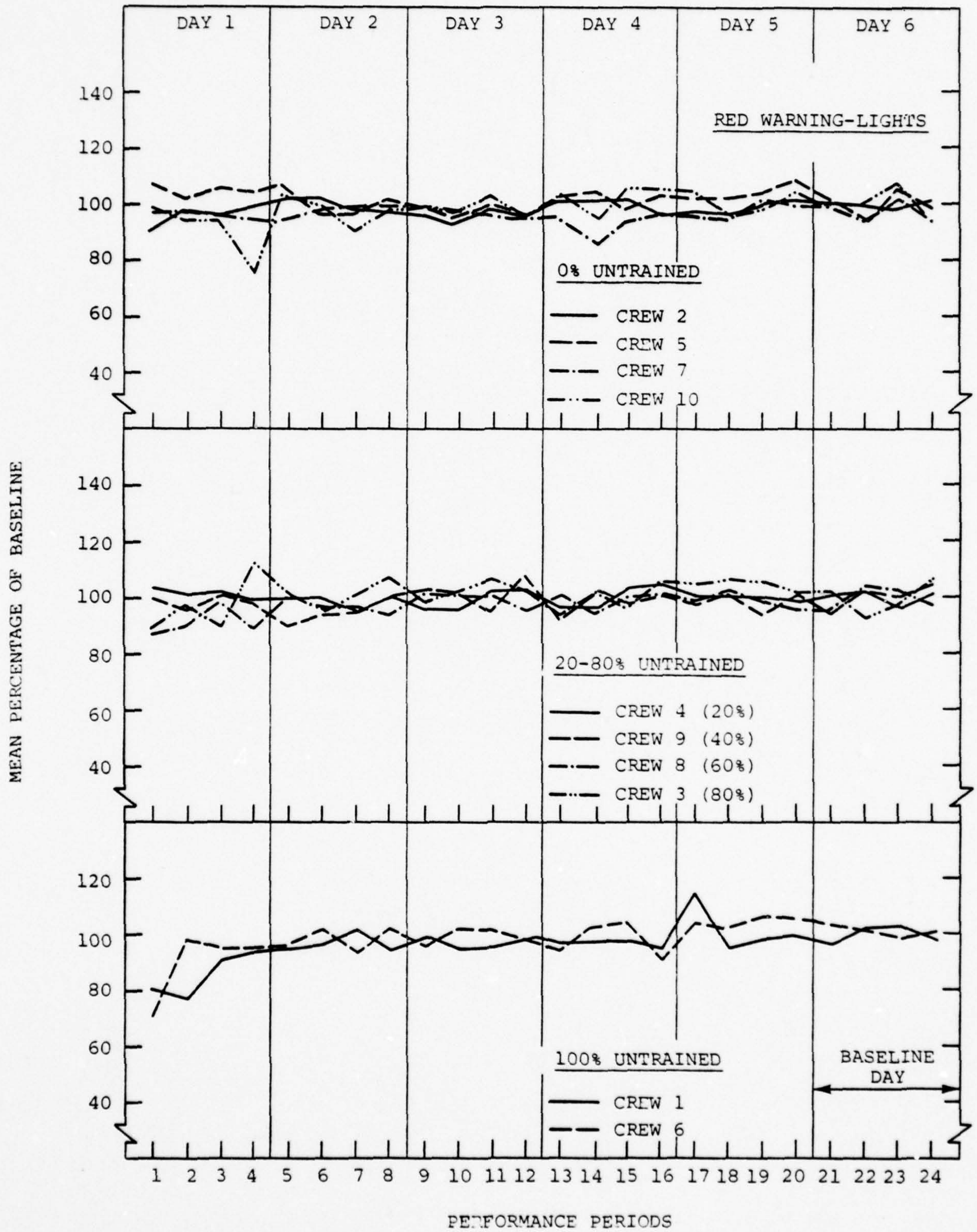

Figure A-1. Mean percentage of baseline of the speed in detecting RED warning-light signals.

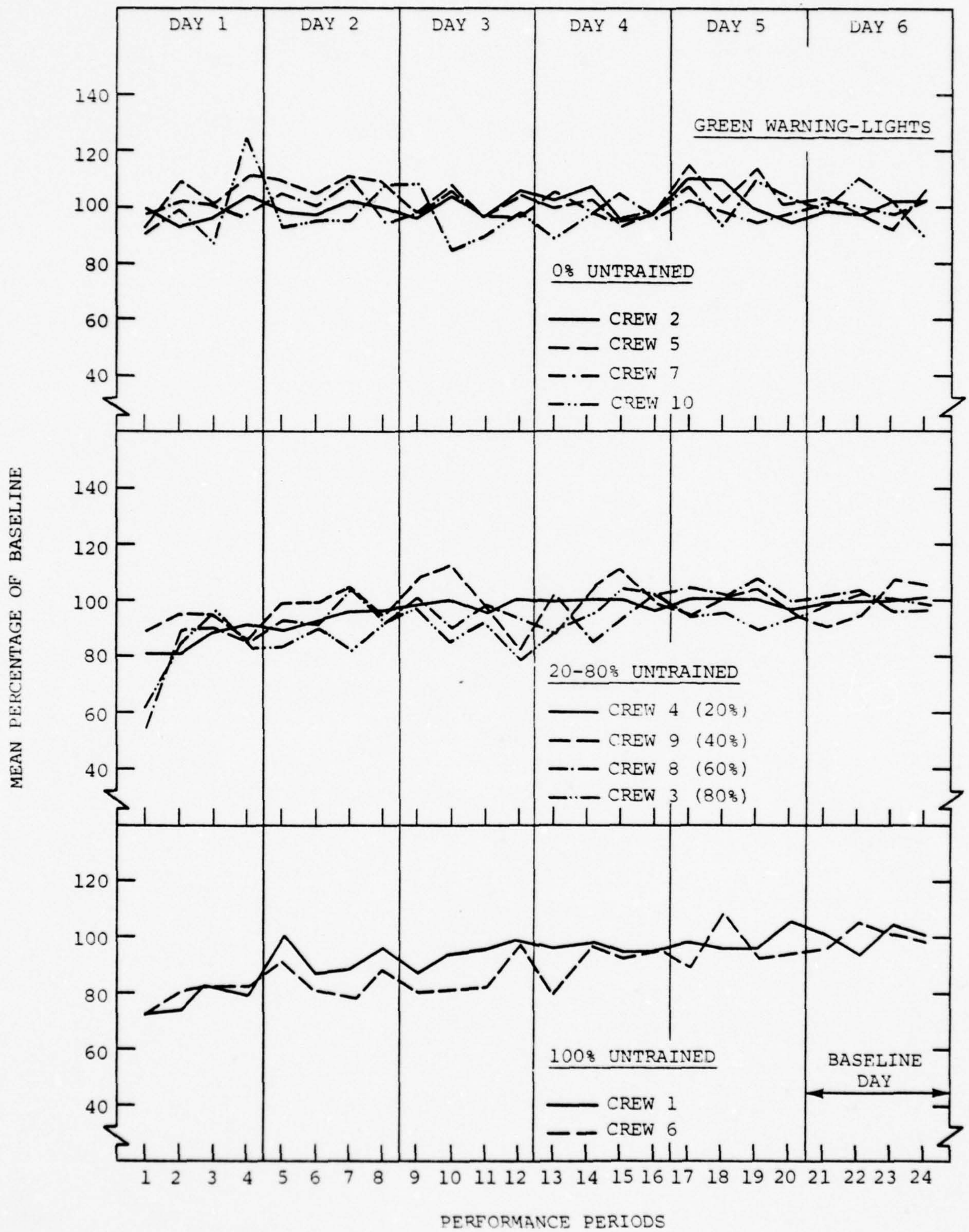

Figure A-2. Mean percentage of baseline of the speed in detecting GREEN warning-light signals.

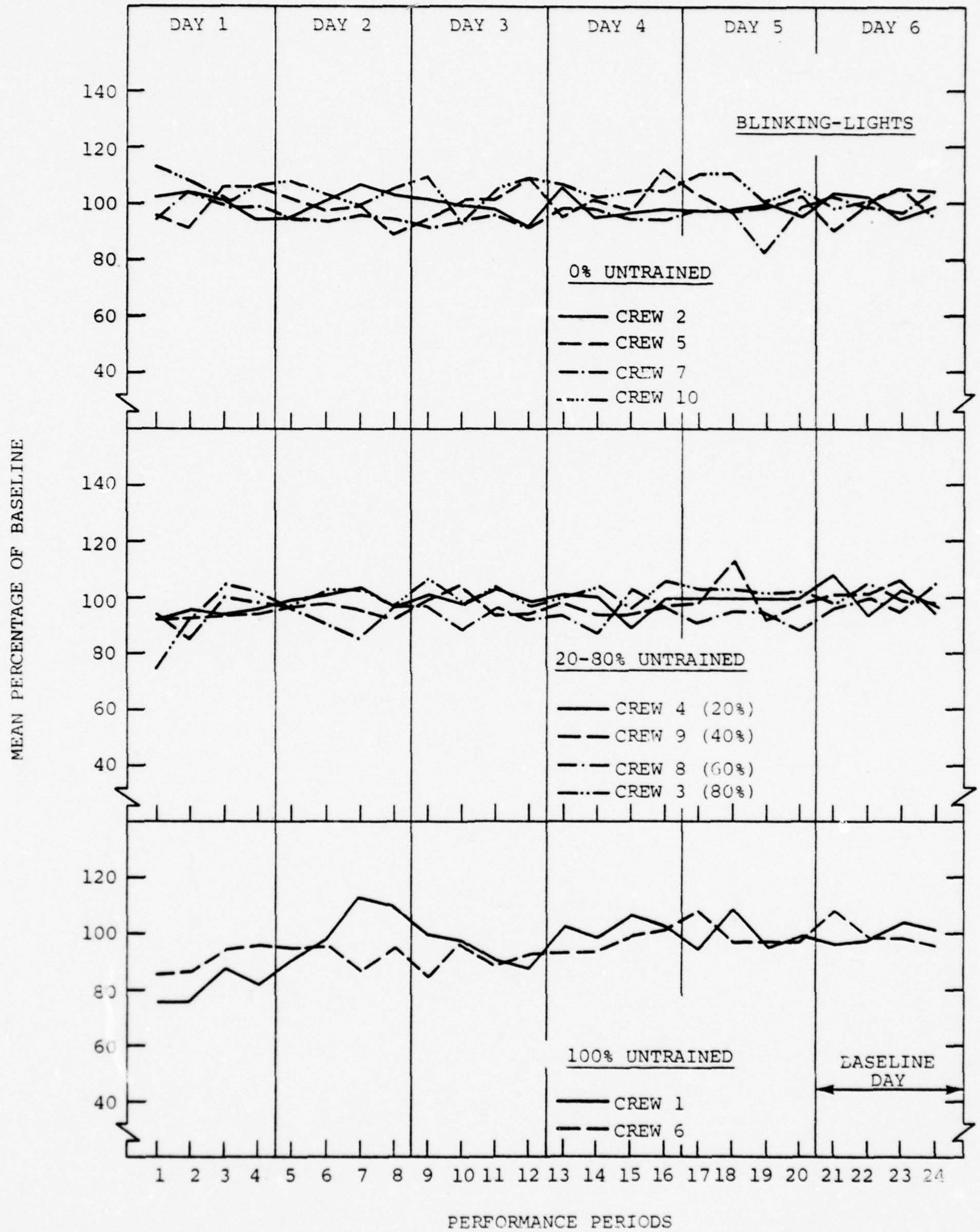

Figure A-3. Mean percentage of baseline of the speed in detecting blinking-lights signals.

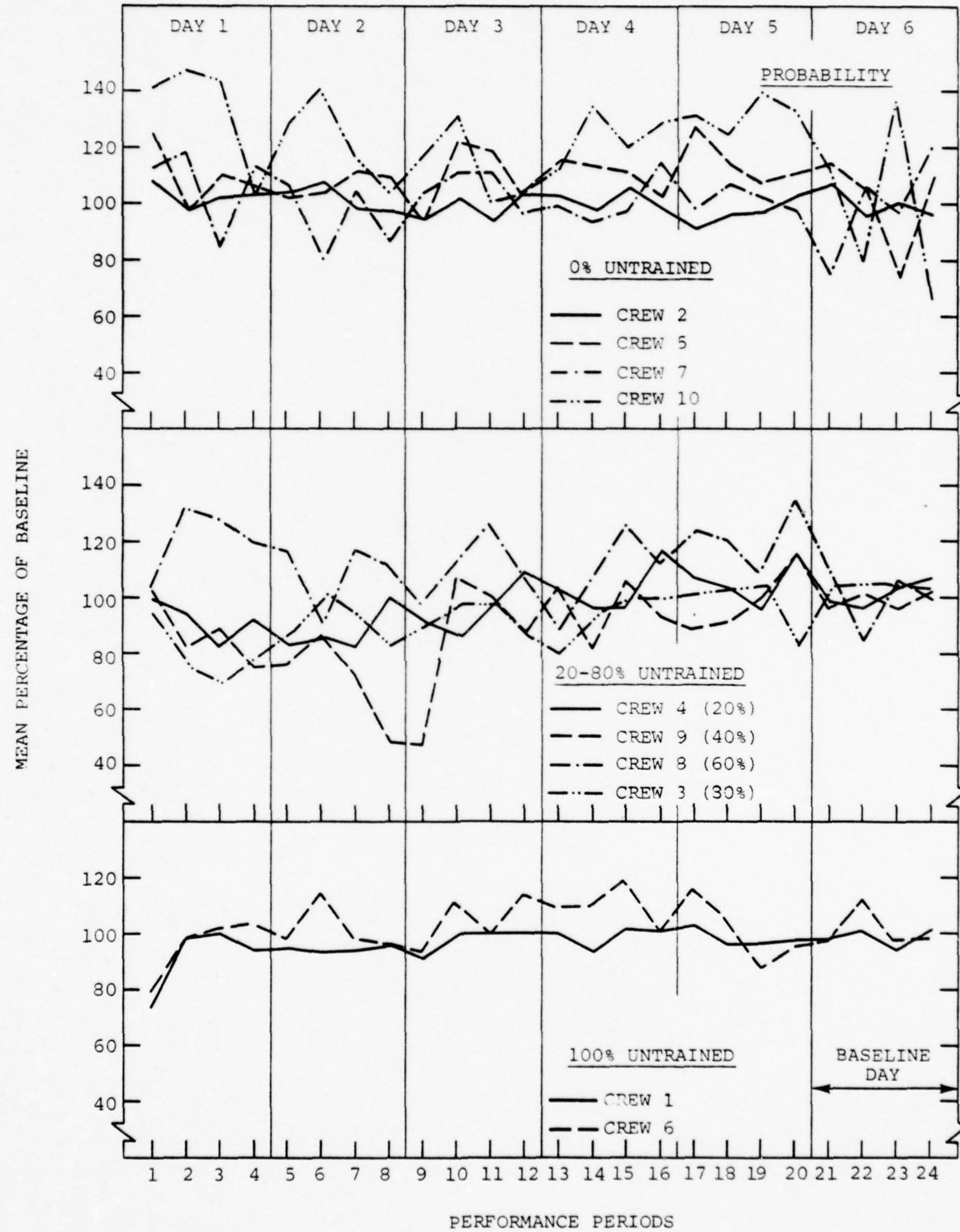

Figure A-4. Mean percentage of baseline of the percentage of correct probability-monitoring signal detections.

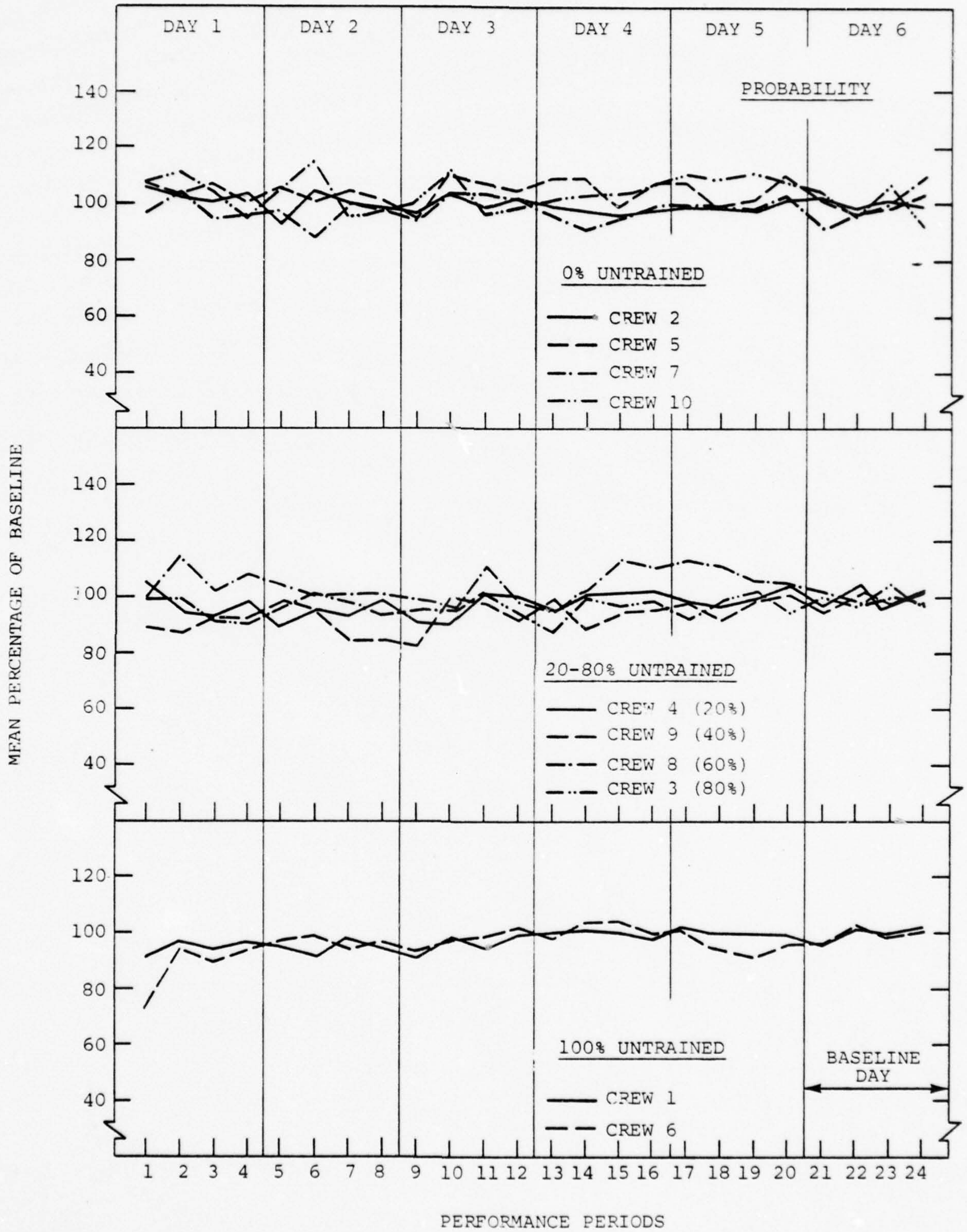

Figure A-5. Mean percentage of baseline of the percentage of probability-monitoring signal present time.

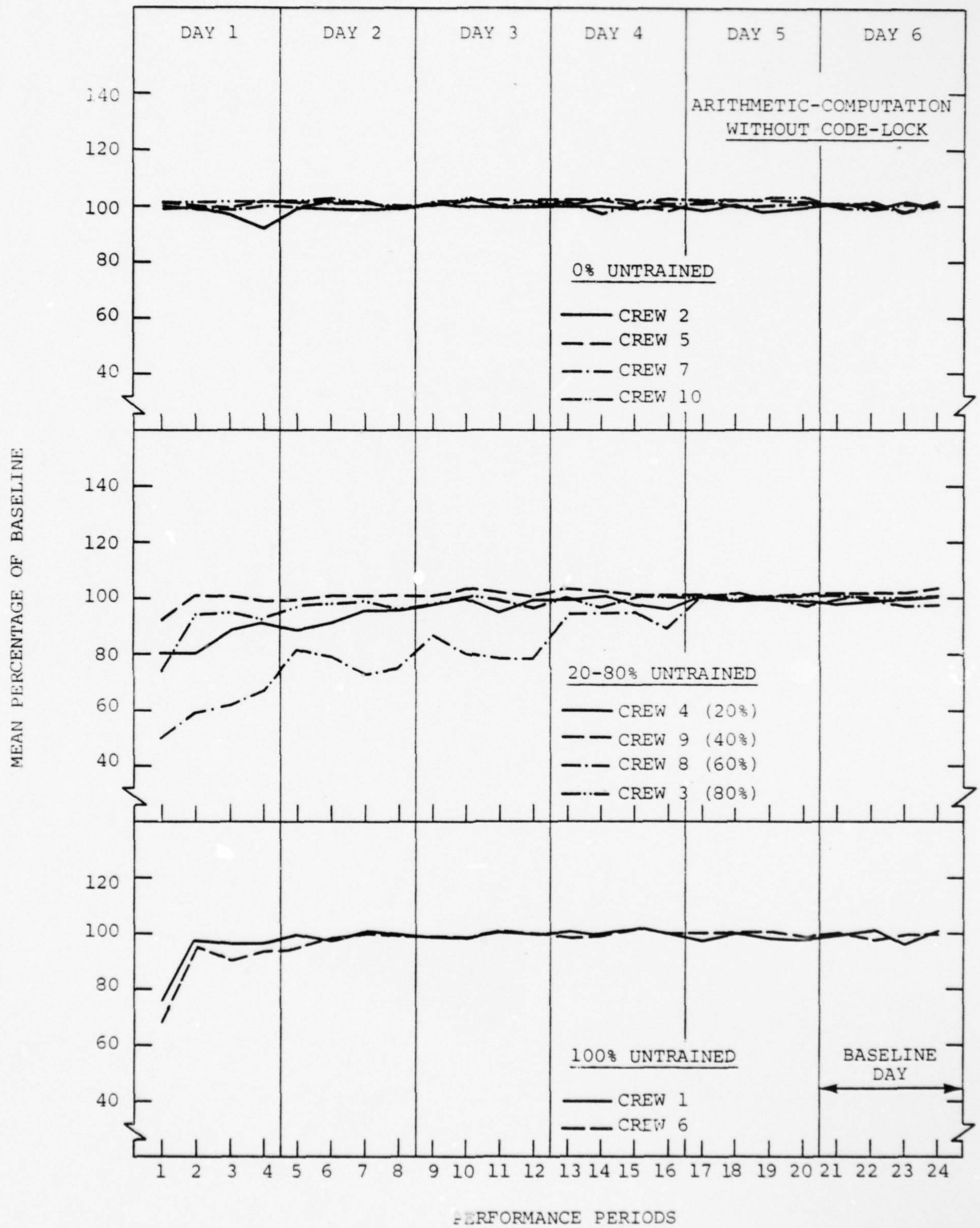

Figure A-6. Mean percentage of baseline of the percentage of arithmetic-computation problems attempted WITHOUT simultaneous code-lock problems.

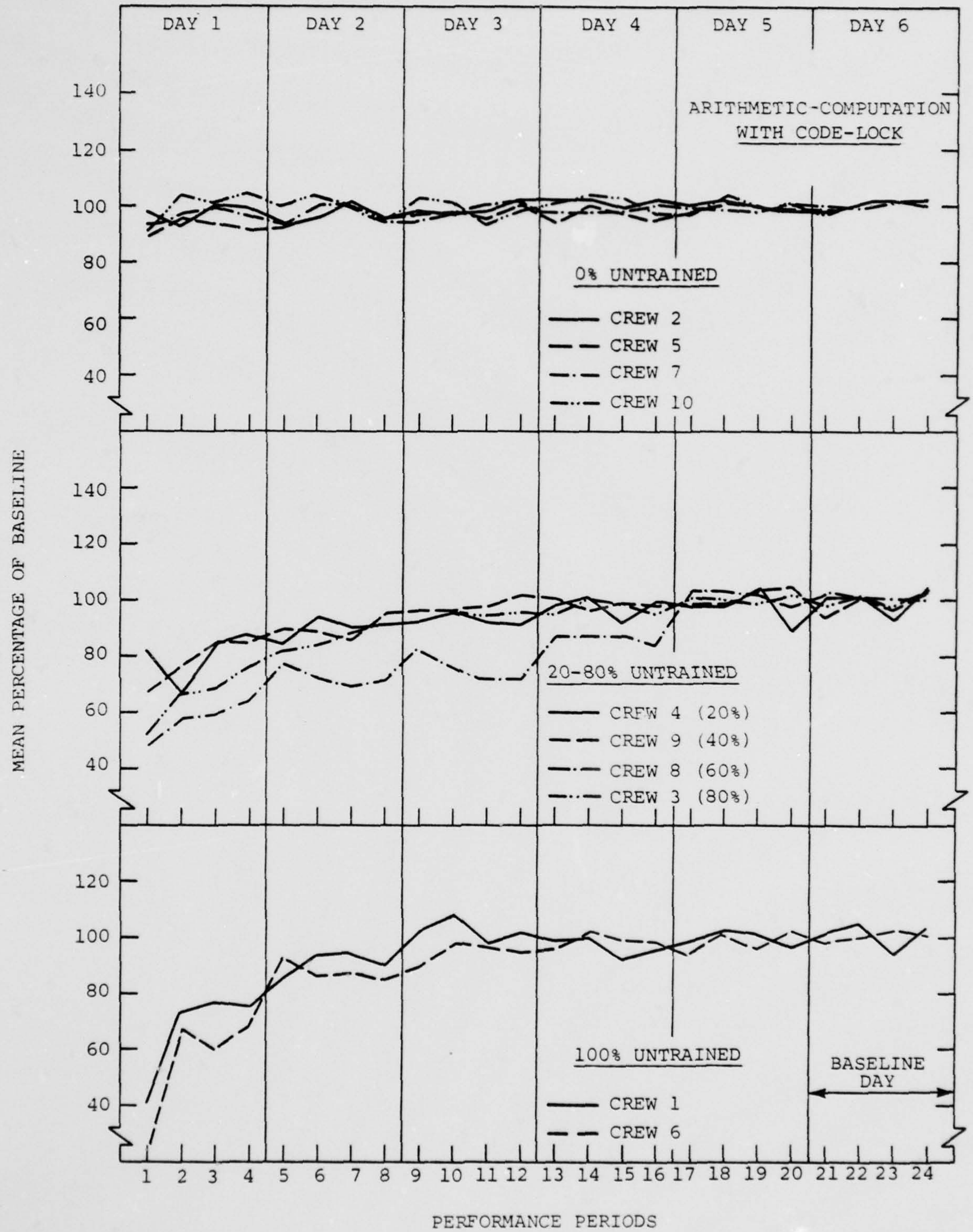

Figure A-7. Mean percentage of baseline of the percentage of arithmetic-computation problems attempted WITH simultaneous code-lock problems.

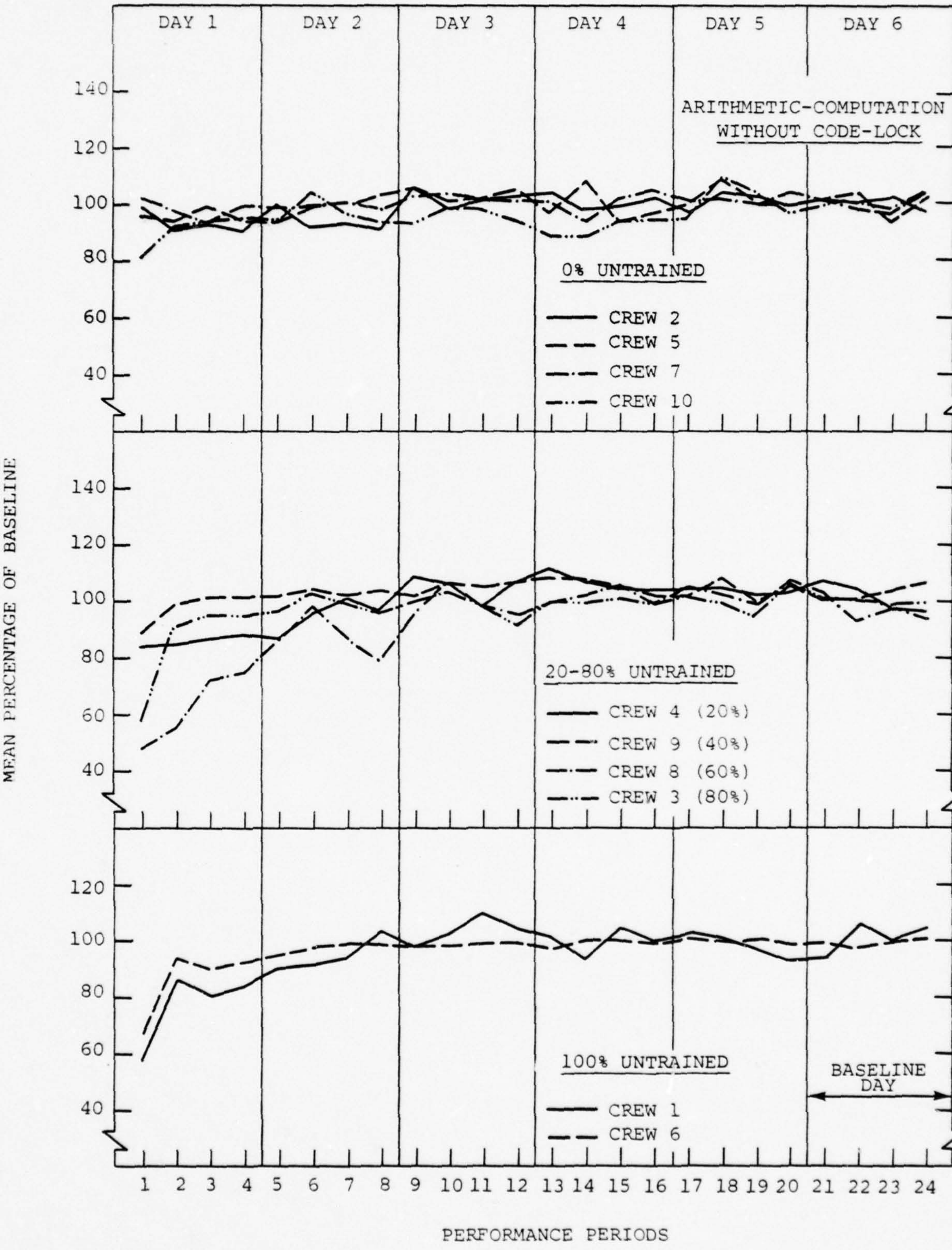

Figure A-8. Mean percentage of baseline of the percentage of correct arithmetic-computation problems WITHOUT simultaneous code-lock problems.

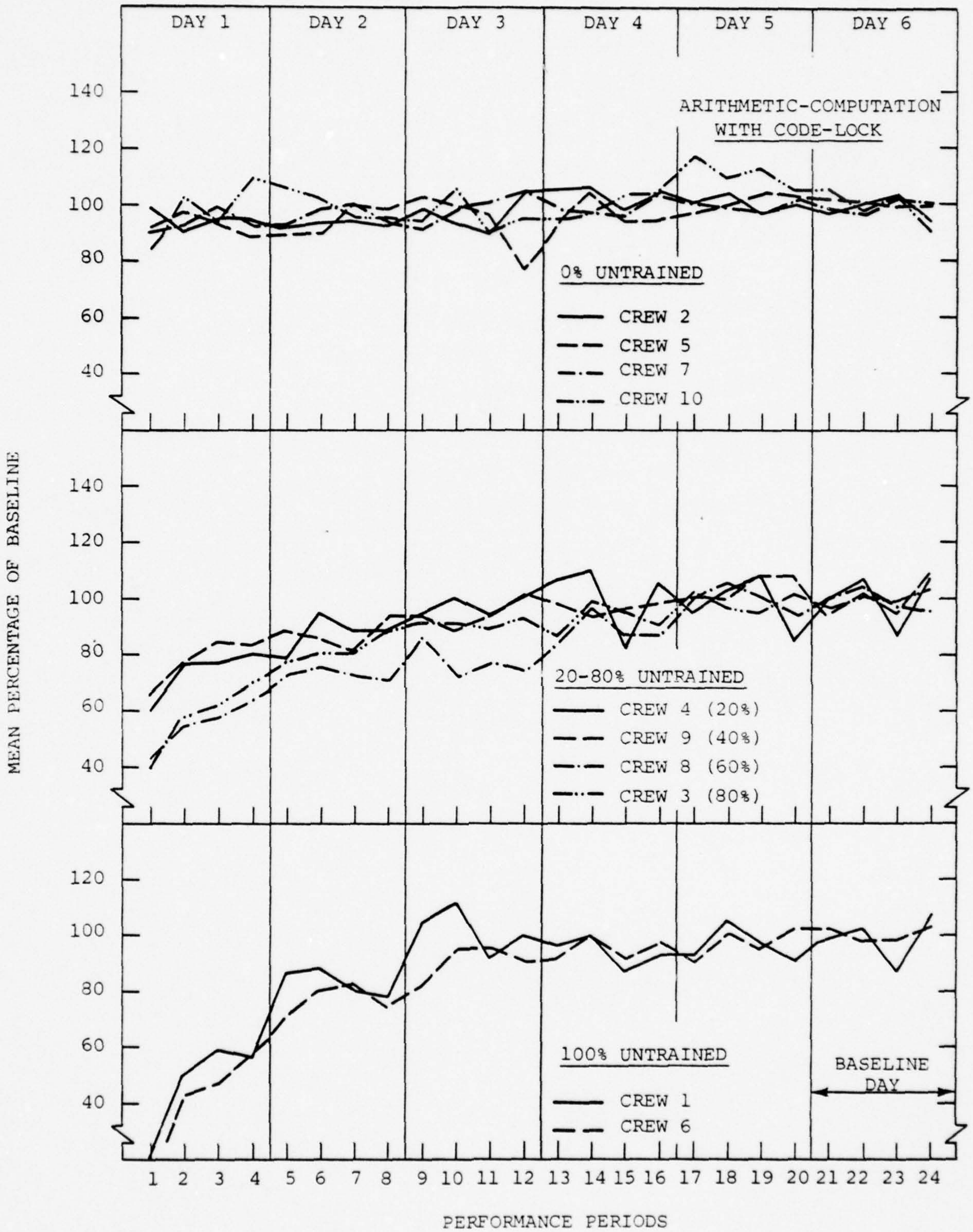

Figure A-9. Mean percentage of baseline of the percentage of correct arithmetic-computation problems WITH simultaneous code-lock problems.

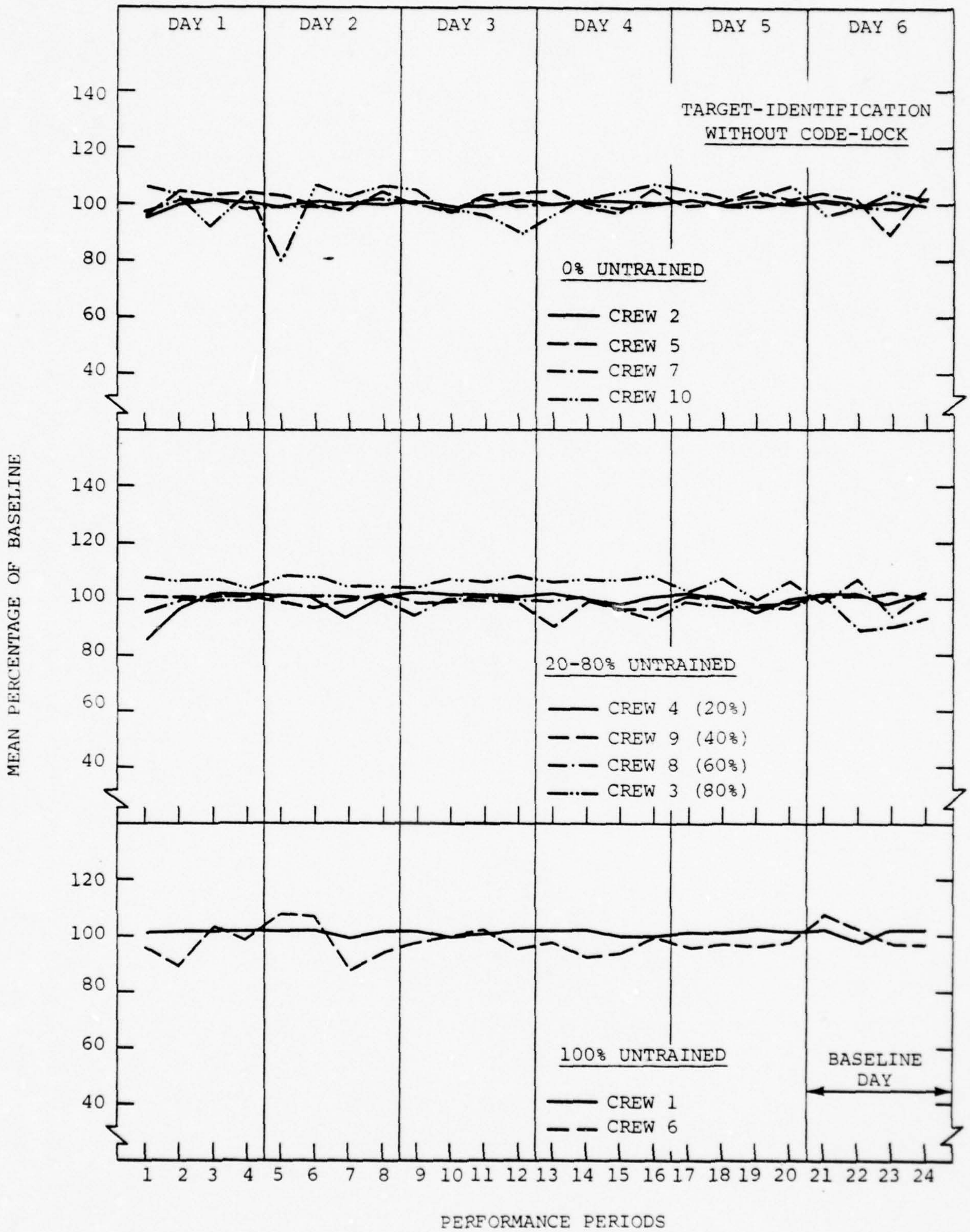

Figure A-10. Mean percentage of baseline of the percentage of target-identification problems attempted WITHOUT simultaneous code-lock problems.

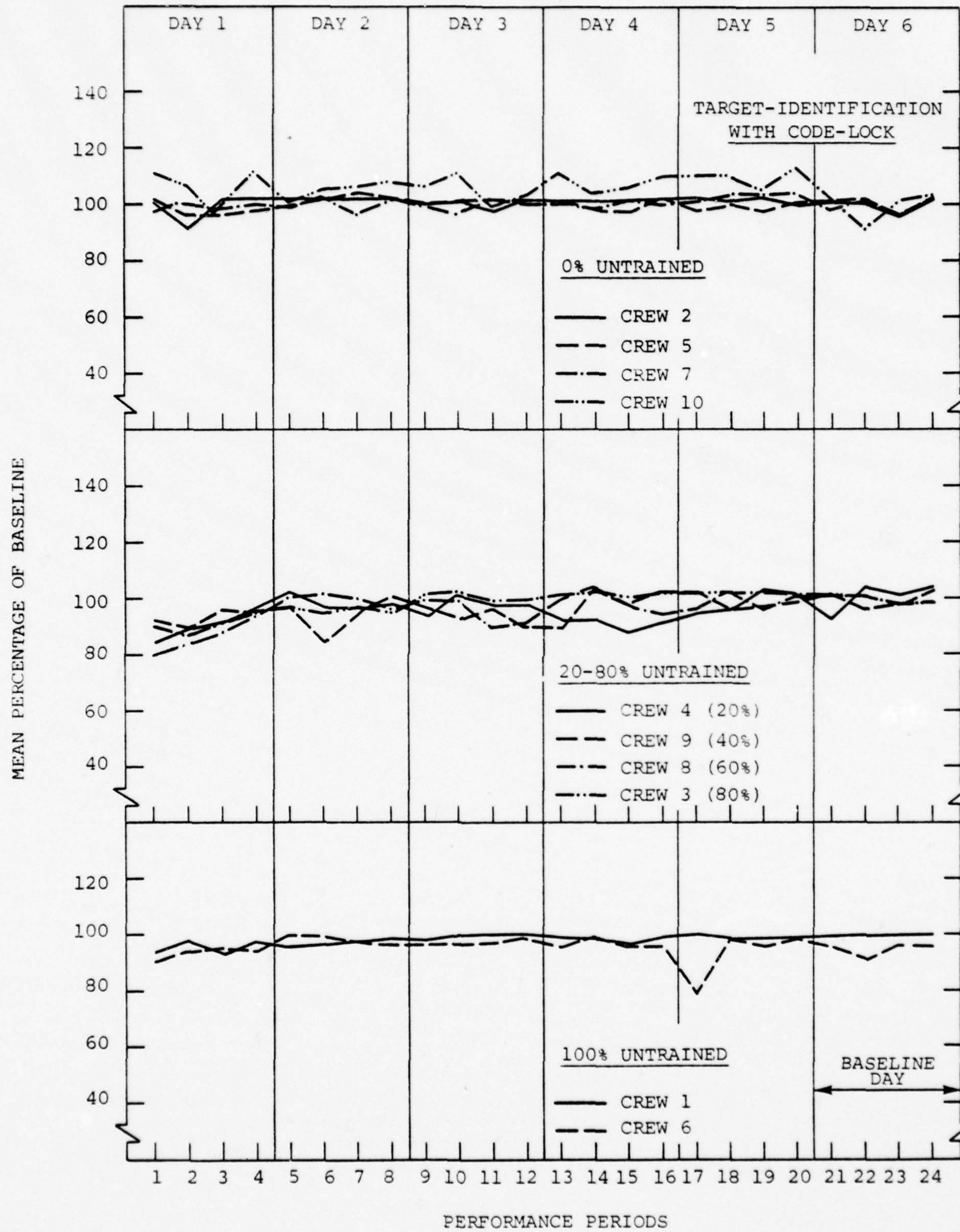

Figure A-11. Mean percentage of baseline of the percentage of target-identification problems attempted WITH simultaneous code-lock problems.

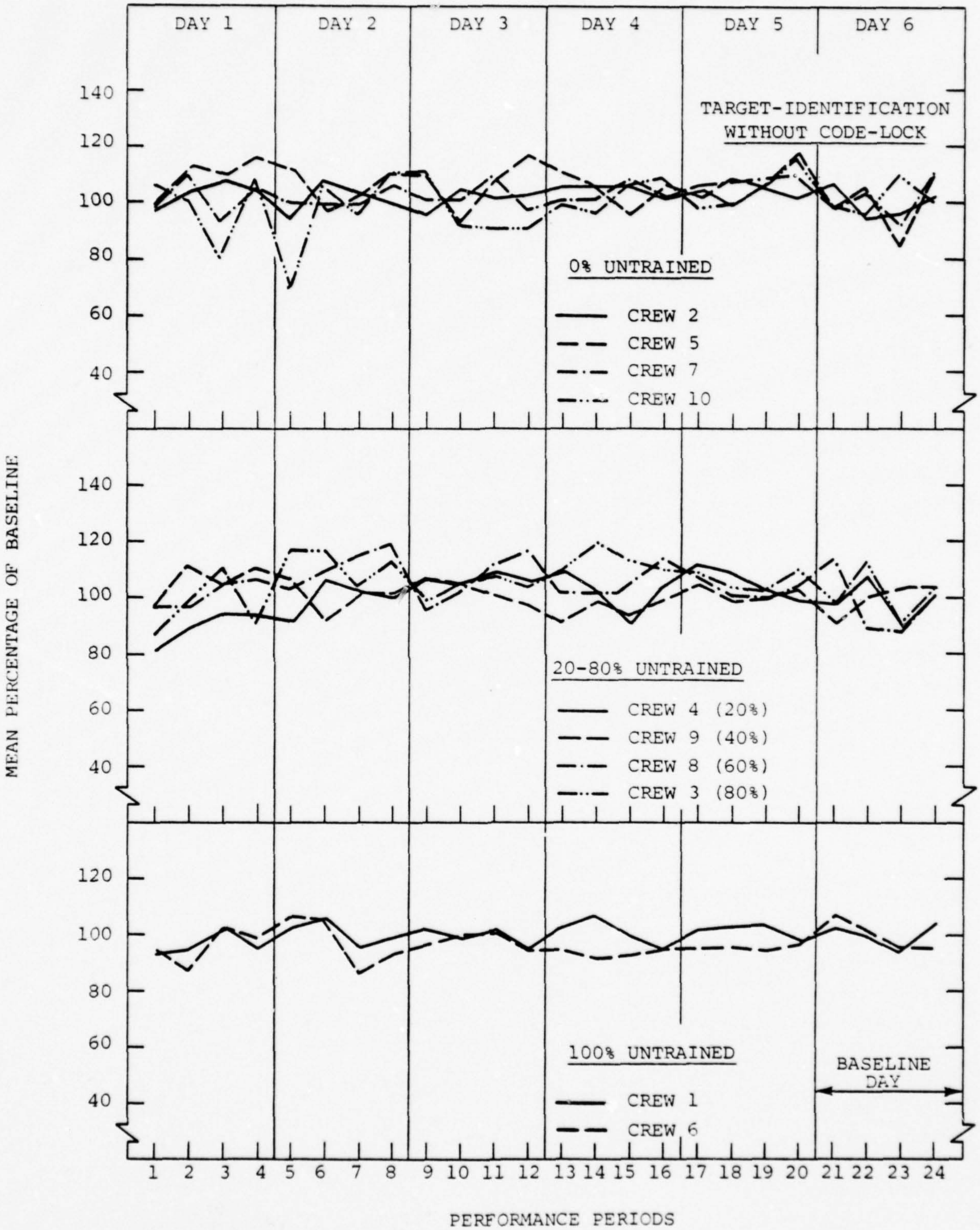

Figure A-12. Mean percentage of baseline of the percentage of correct target-identification problems WITHOUT simultaneous code-lock problems.

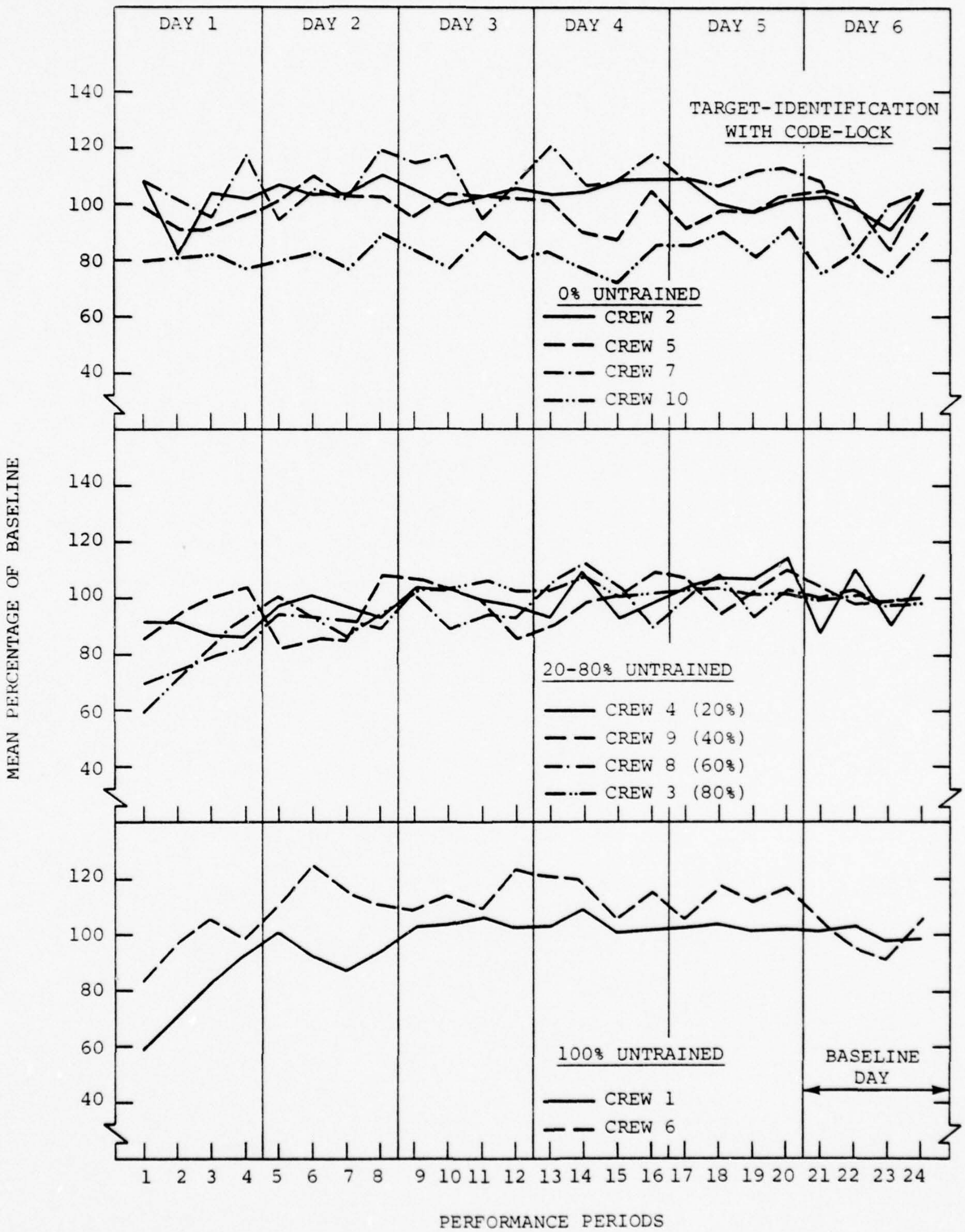

Figure A-13. Mean percentage of baseline of the percentage of correct target-identification problems WITH simultaneous code-lock problems.

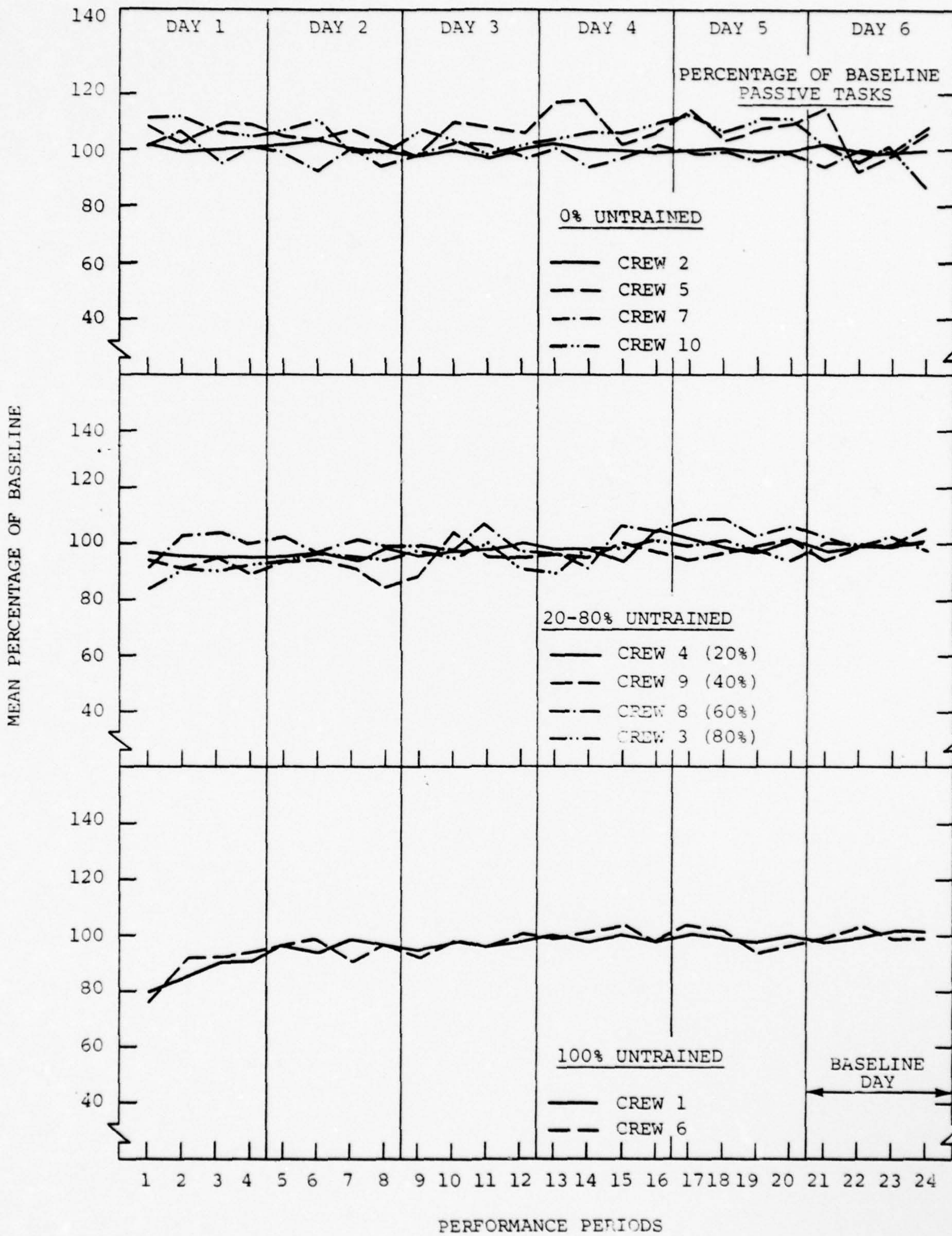

Figure A-14. Mean percentage of baseline performance of the combined watchkeeping tasks.

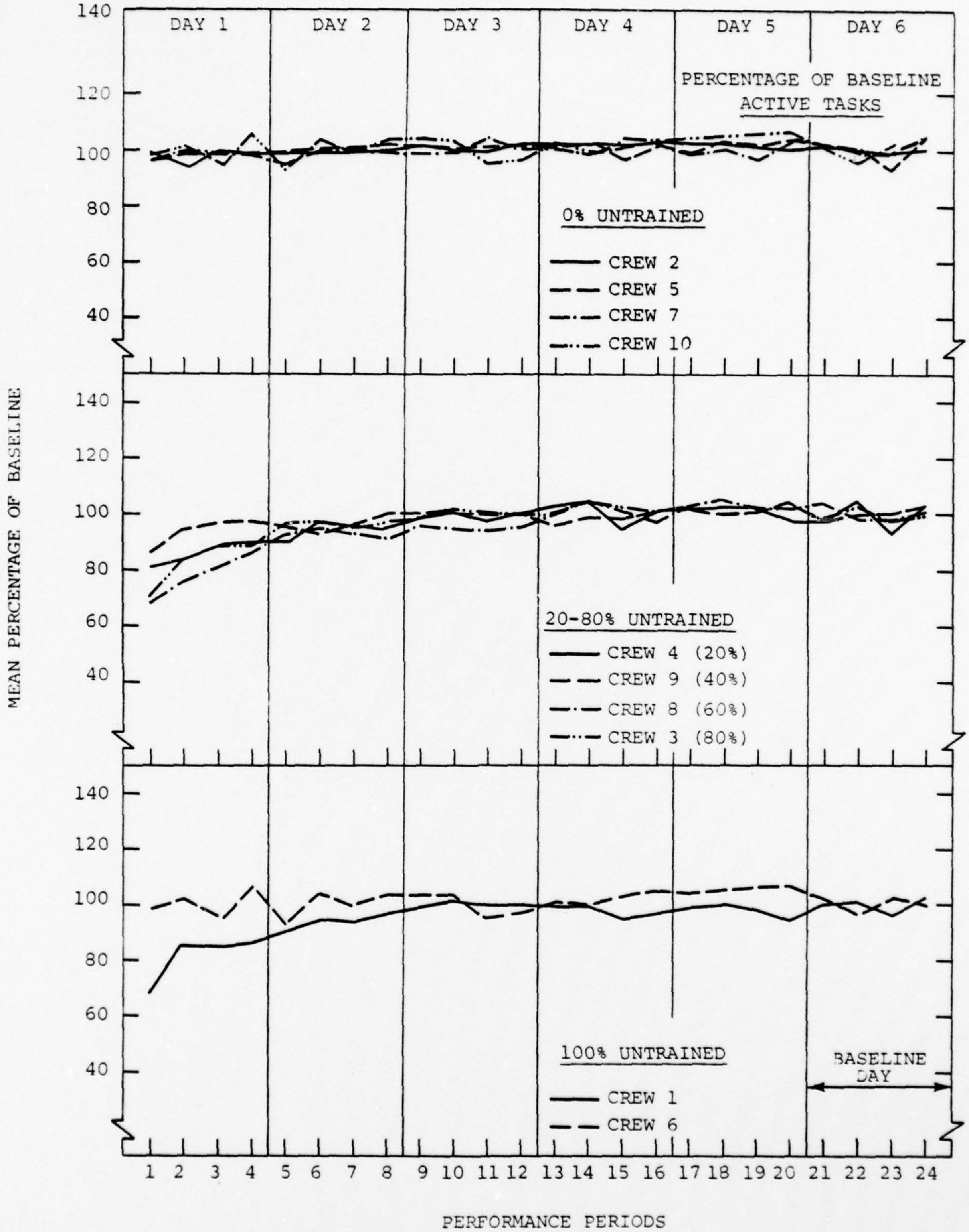

Figure A-15. Mean percentage of baseline performance of the combined active tasks.

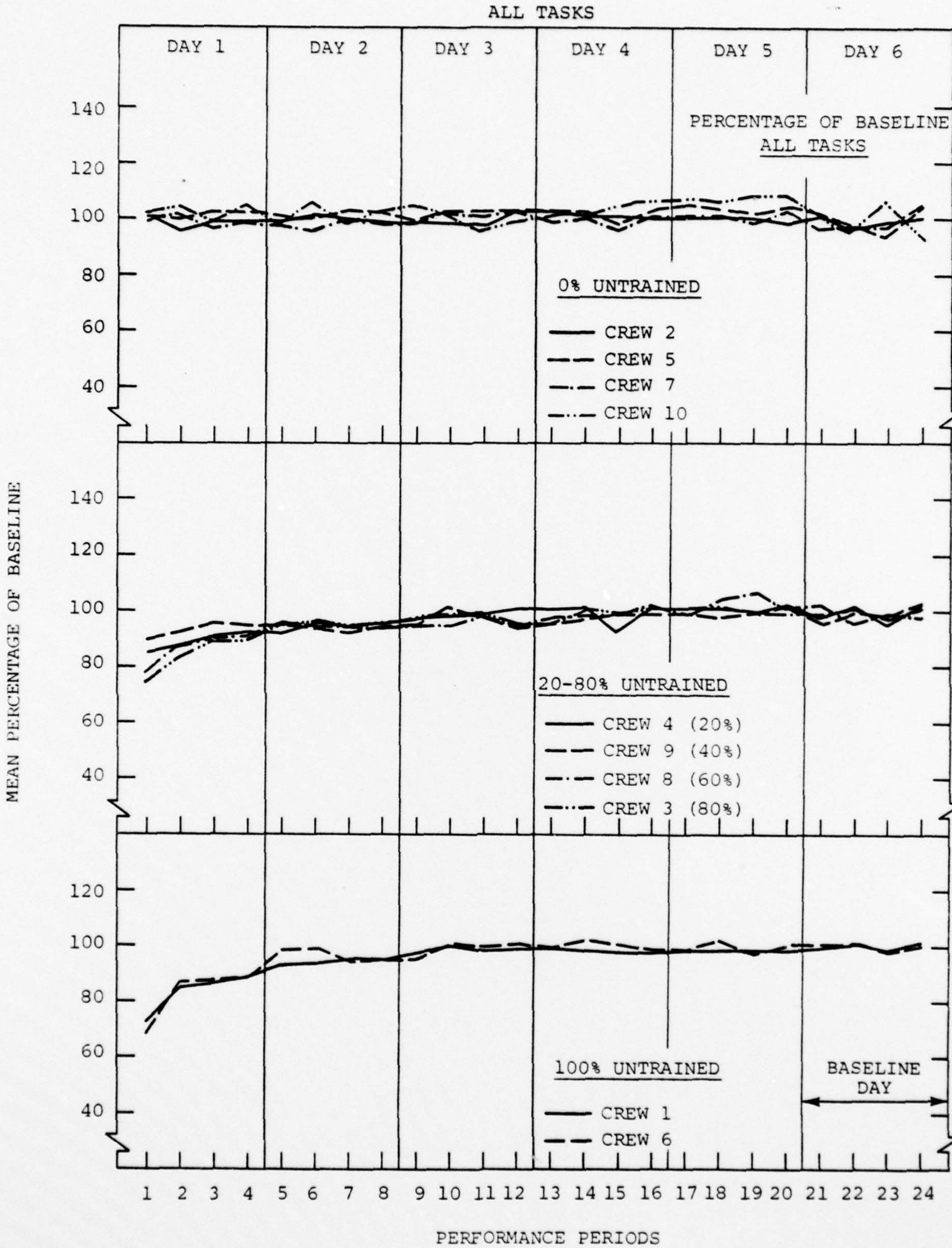

Figure A-16. Mean percentage of baseline performance of all tasks combined.

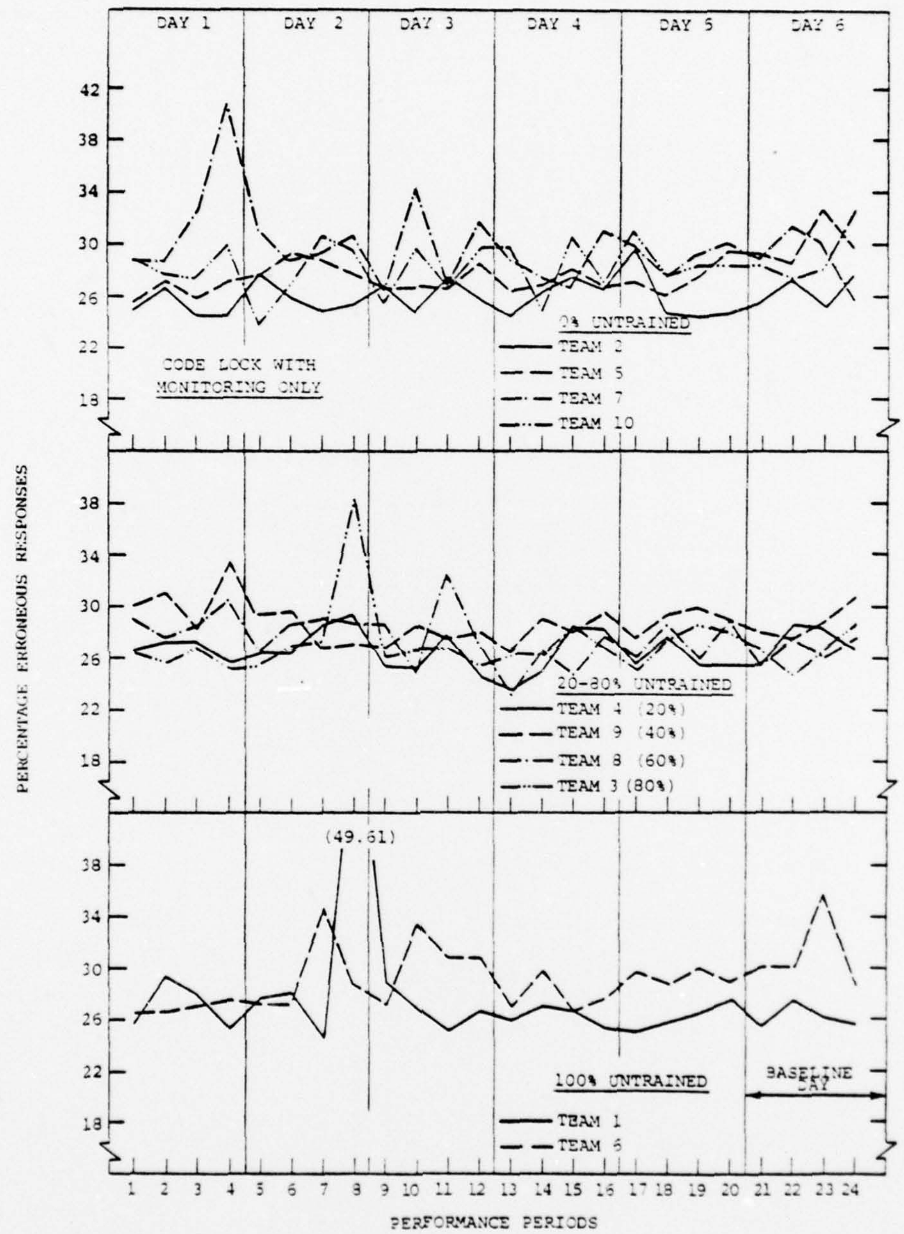

Figure A-17. Mean percentage of erroneous code-lock responses with watchkeeping tasks only.

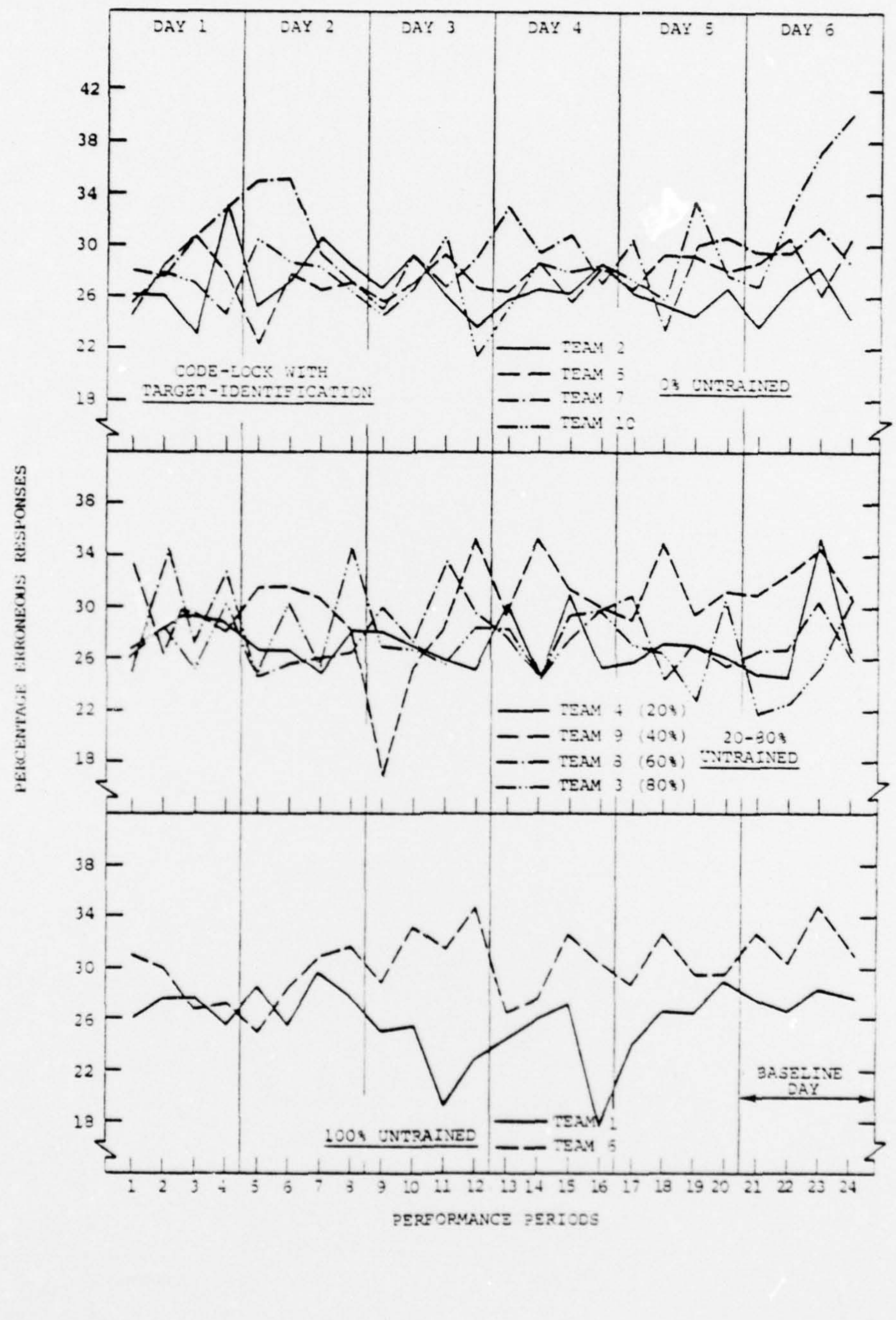

Figure A-18. Mean percentage of erroneous code-lock responses with watchkeeping and target identification tasks.

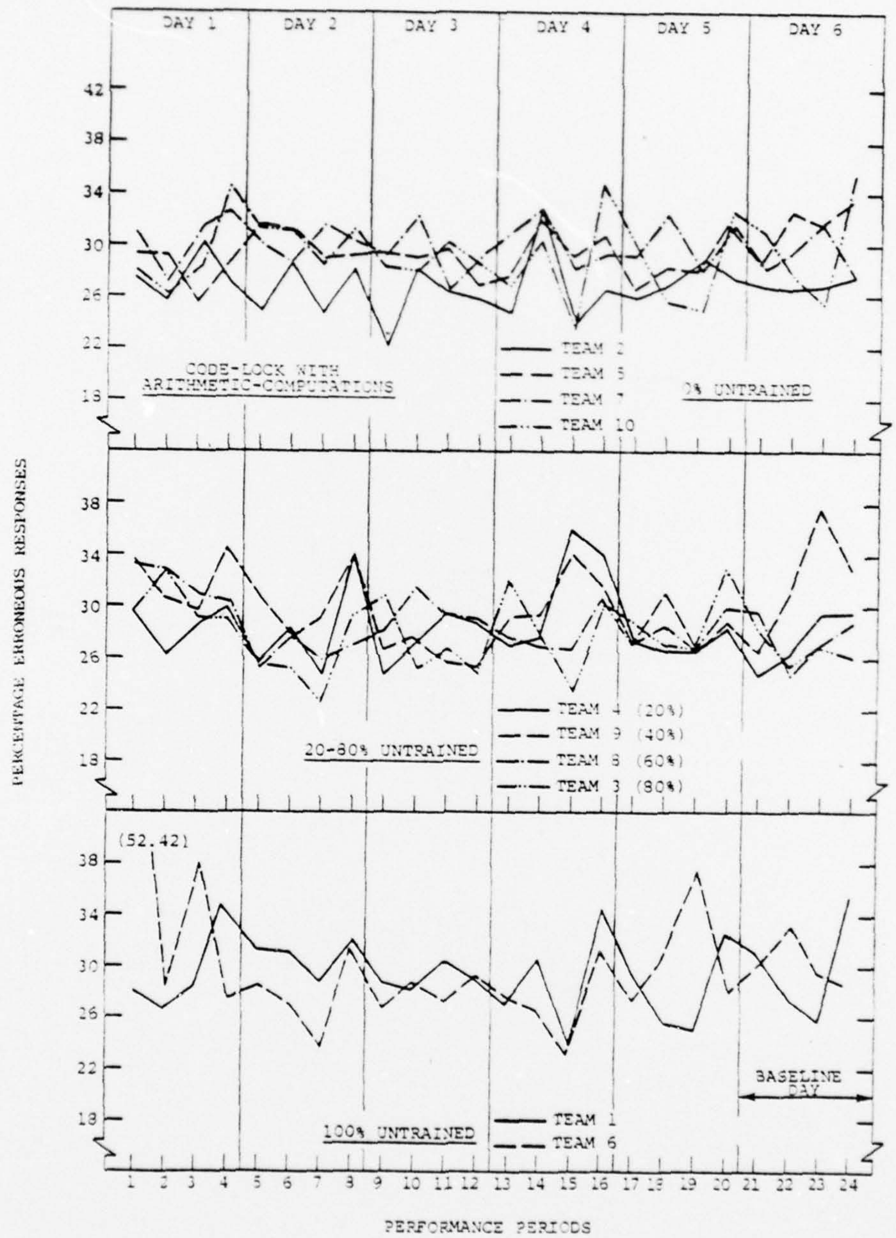

Figure A-19. Mean percentage of erroneous code-lock responses with watchkeeping and arithmetic computation tasks.

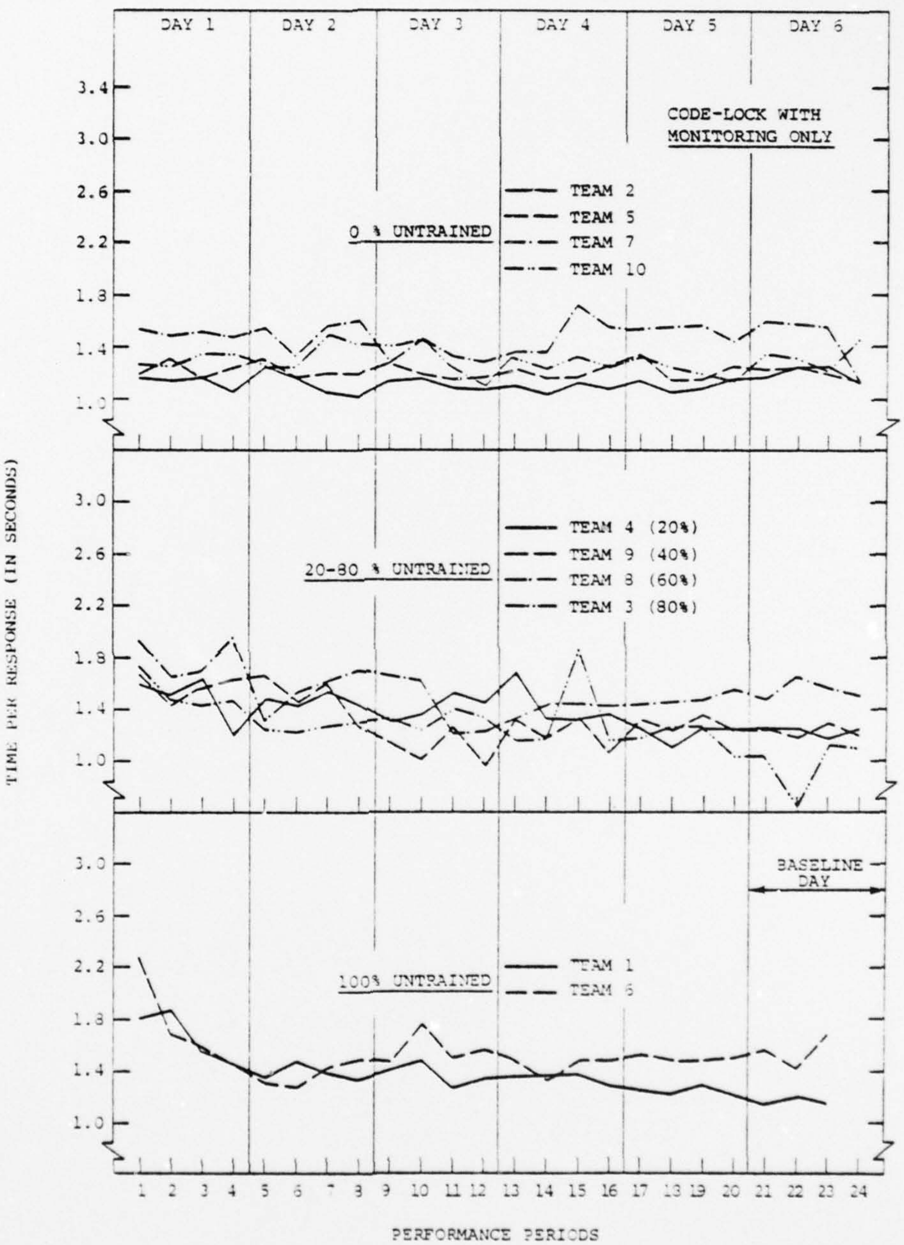

Figure A-20. Mean time per code-lock response with watchkeeping tasks only.

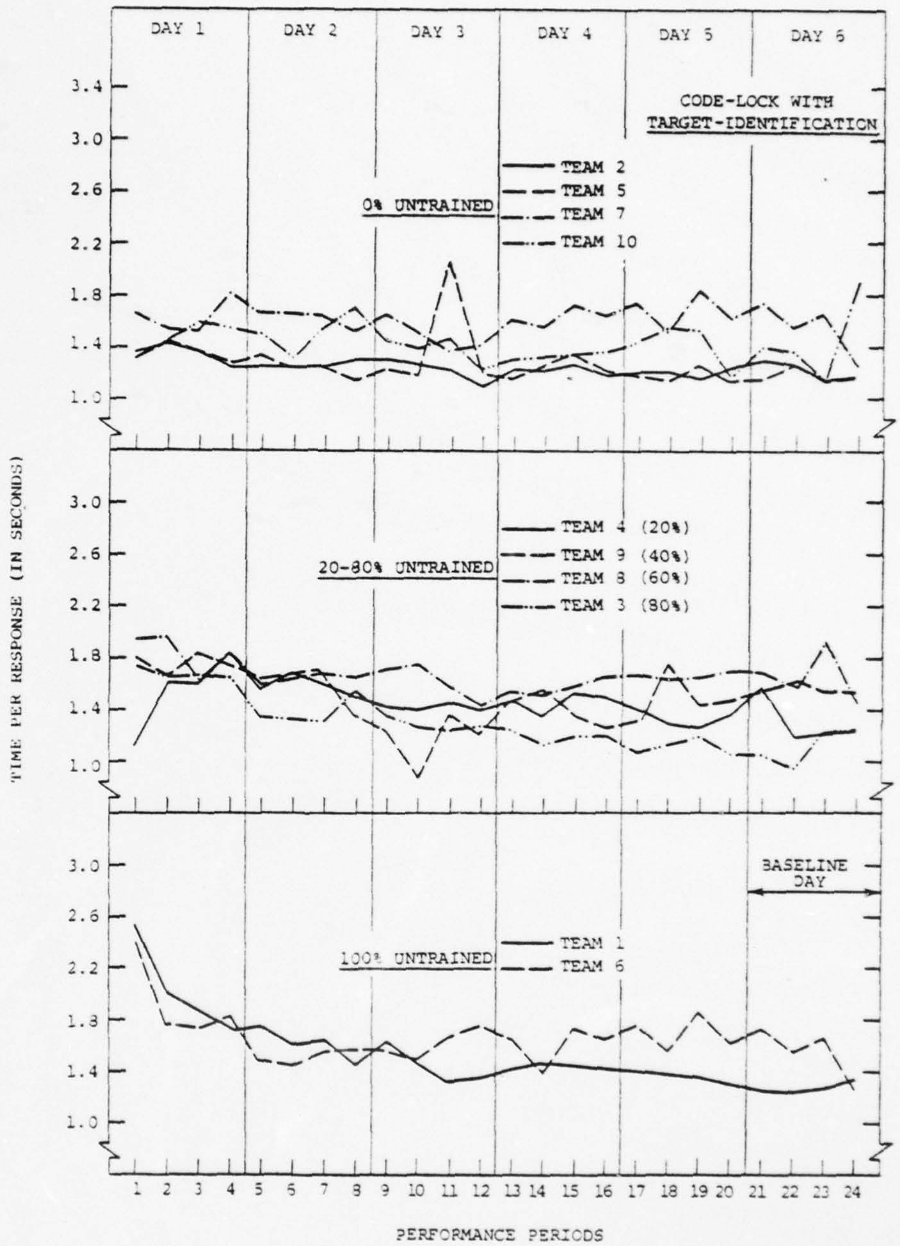

Figure A-21. Mean time per code-lock response with watchkeeping and target identification tasks.

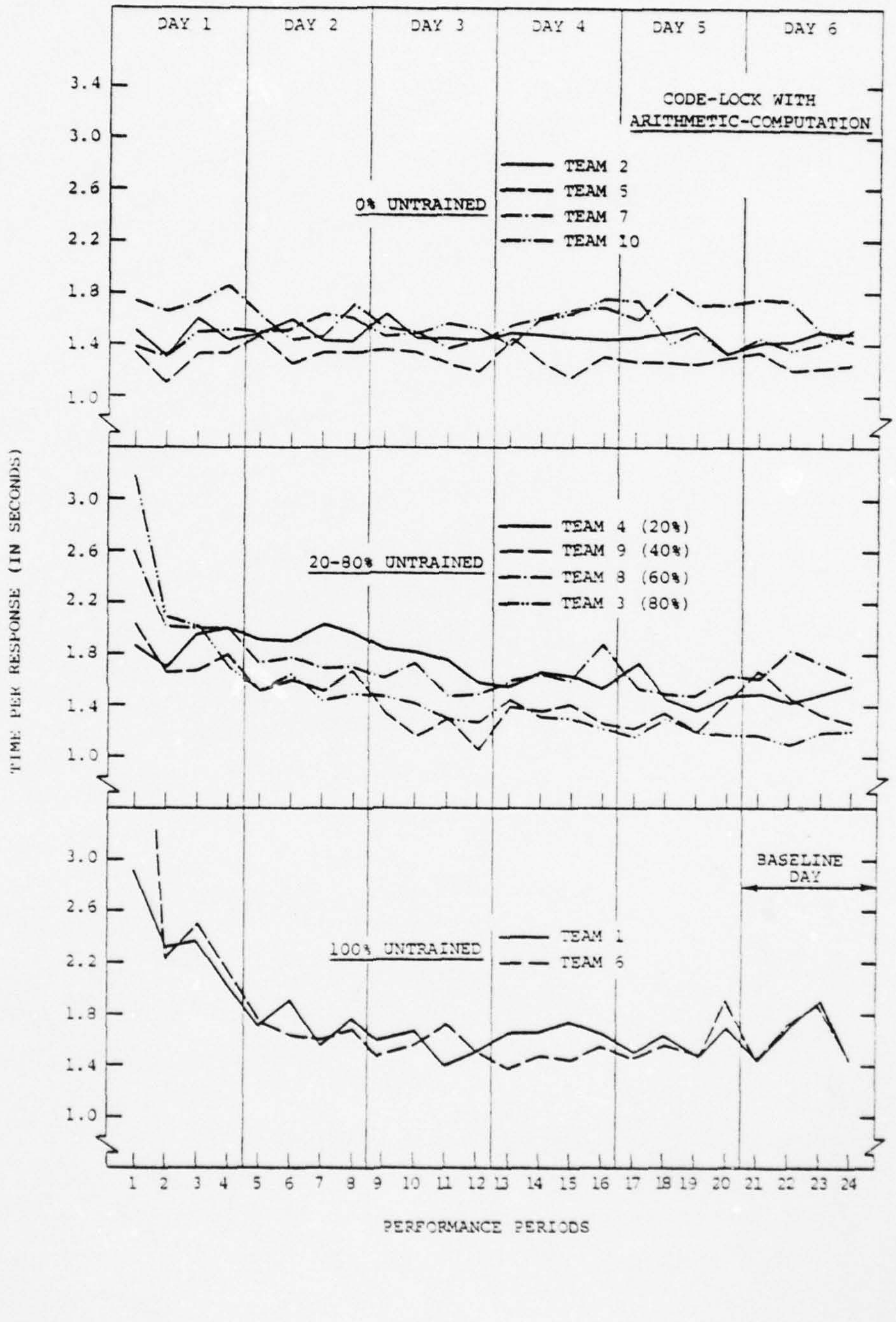

Figure A-22. Mean time per code-lock response with watchkeeping and arithmetic computation tasks.

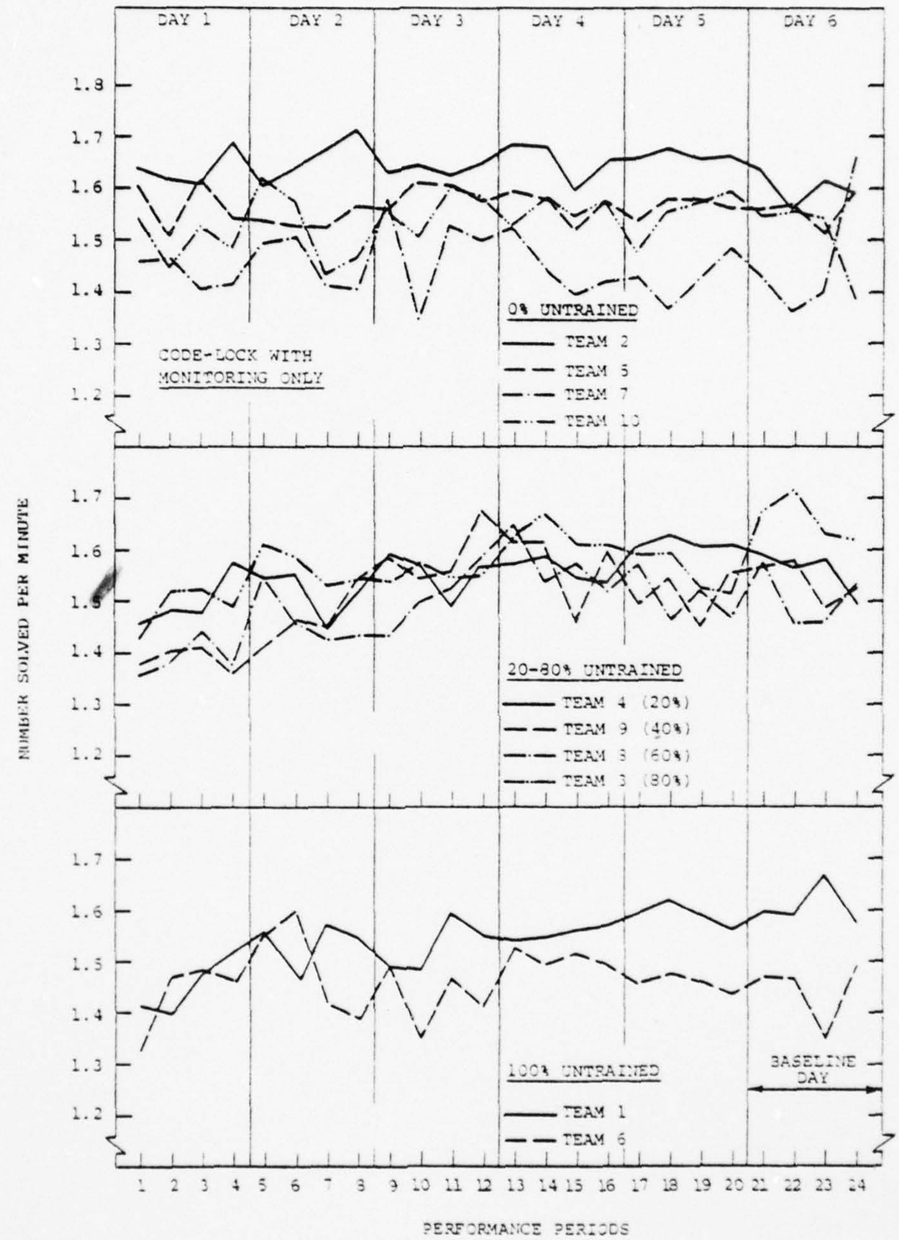

Figure A-23. Mean number of code-lock problems solved per minute and relative rate of information transmission per period with watchkeeping tasks only.

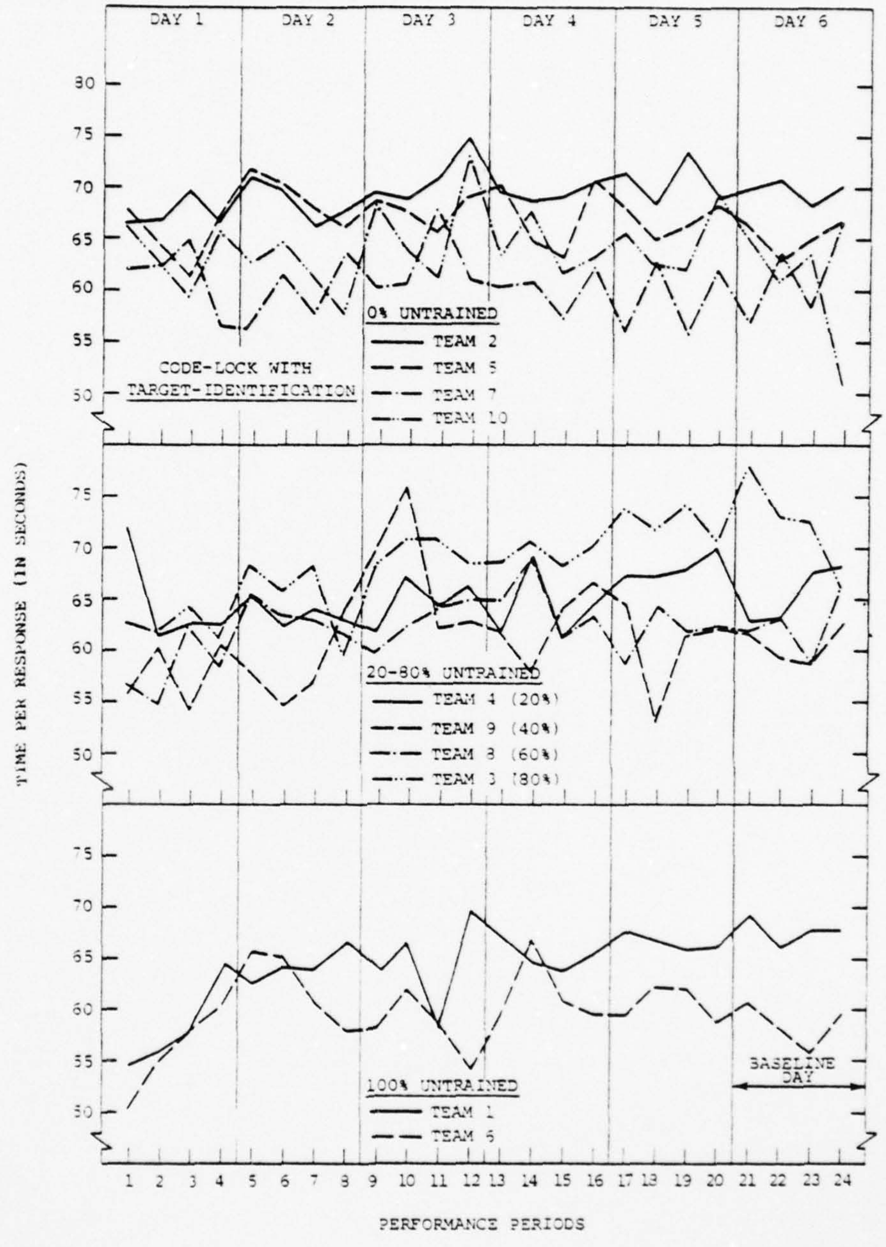

Figure A-24. Mean number of code-lock problems solved per minute and relative rate of information transmission per period with watchkeeping and target identification tasks.

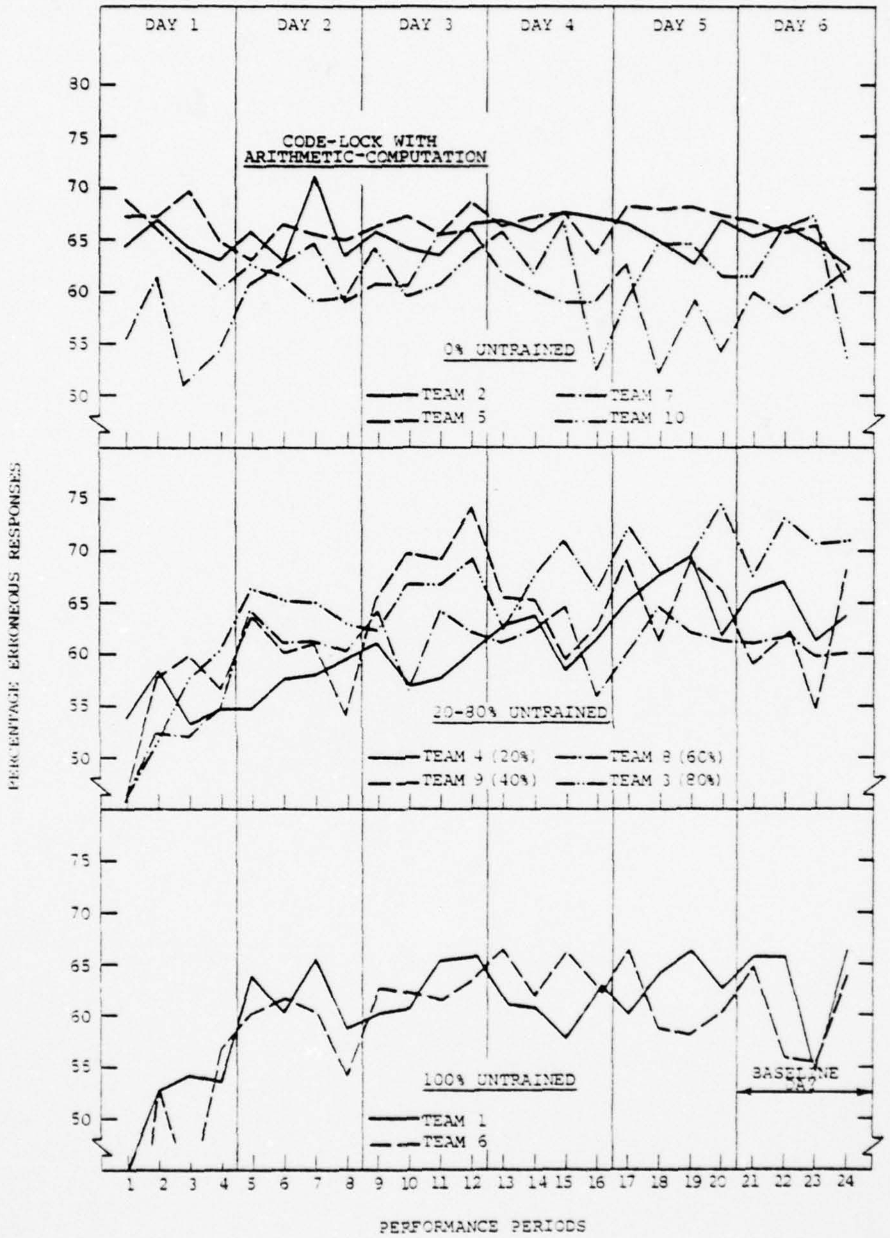

Figure A-25. Mean number of code-lock problems solved per minute and relative rate of information transmission per period with watchkeeping and arithmetic computation tasks.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the results of two series of studies of team training conducted during the summer of 1977. In each of ten studies, five subjects worked together as a team for 8 hours per day over 6 consecutive days; during their first 48 hours of work, each team was trained to perform the six tasks that constitute the synthetic work presented with the Multiple-Task Performance Battery. The ten teams consisted of different combinations of the total of 20 undergraduate male volunteer subjects to provide team-training loads (percentages of untrained team personnel) ranging from 0 to

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100% in 20% steps. The data of the ten studies were combined to permit analysis of the effects of team-training loads ranging from 0 to 100% in 10% steps, and the effects of team-training load on training and performance effectiveness were thereby assessed.

The results indicated that the substitution of untrained personnel into a trained team reduces the performance effectiveness of the team (in terms of both average individual-skill performances and team-skill performances) in direct proportion to the percentage of untrained team personnel. In all cases, this was a function of the lower performances of the untrained team members; performances of the trained individuals was not adversely affected by increases in the team-training load. Both individual- and team-skill performances recovered to asymptotic (baseline) levels after a constant amount of collective training for all team-training loads. Thus, the percentage of untrained personnel in the team had no influence on the effectiveness of the training. Differences in individual- and team-skill performances suggested that the latter are more resistant to adverse effects at the lower levels of team-training loads; with 10% untrained personnel, team-skill performances were only slightly affected.

The implications of these results for optimizing team-training strategies and maintenance of high levels of team-performance effectiveness are discussed, and verification by field testing is recommended.